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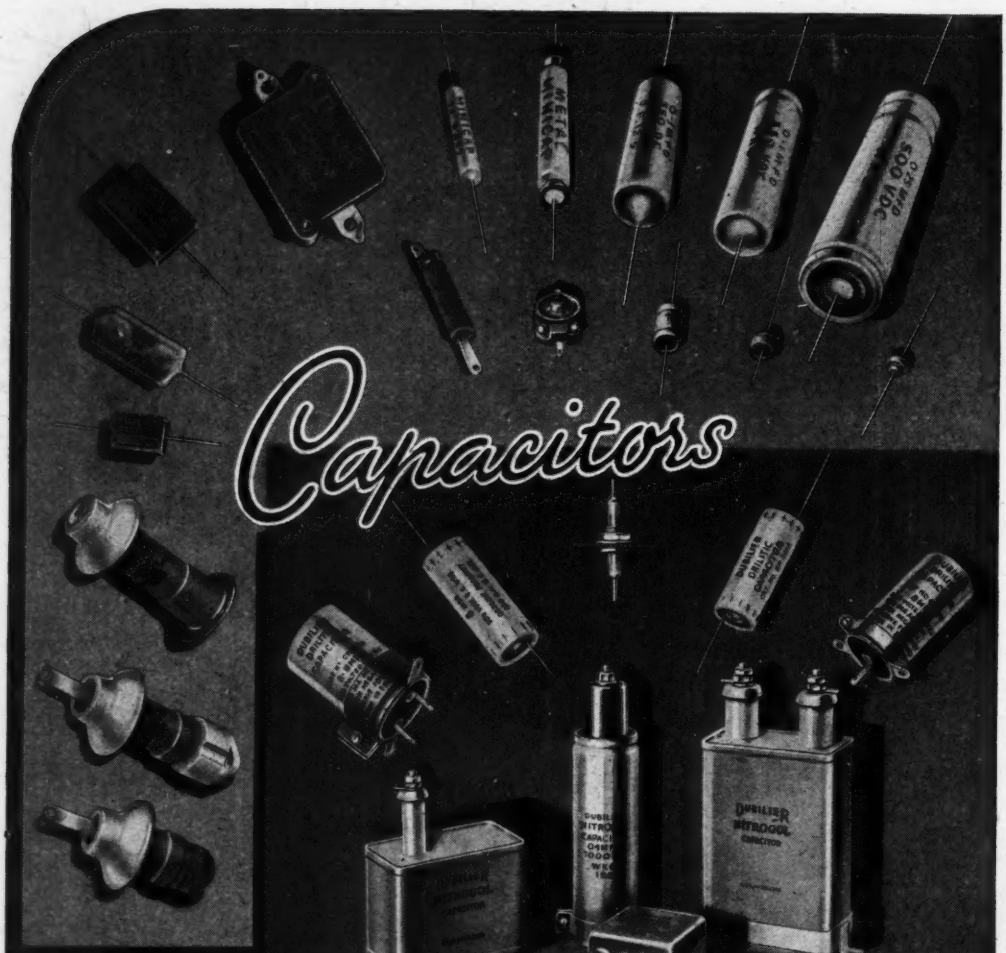
Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

An Electronic Decimal Counter Chronometer
A Universal Oscillograph
Load Conditions in Class A Triode Amplifiers
A Modification to Ray Theory Allowing for Ground Contours
Perfect v. Pleasing Reproduction

2/- JAN., 1947



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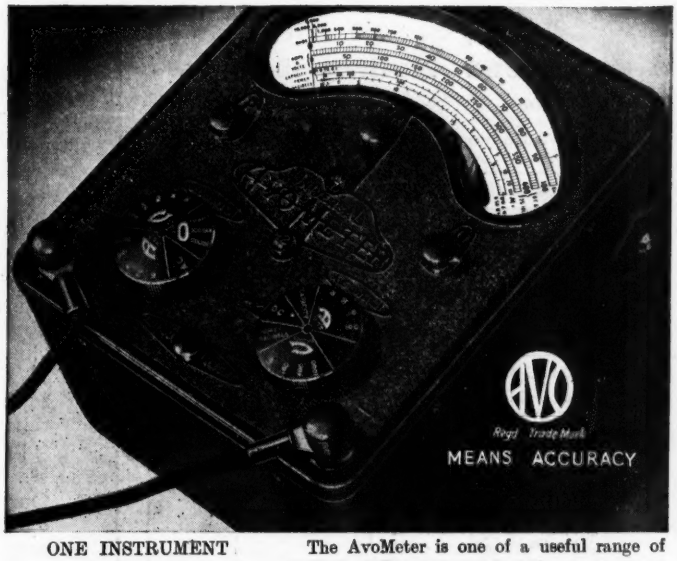

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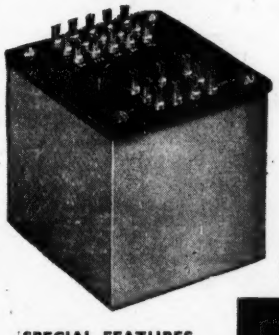

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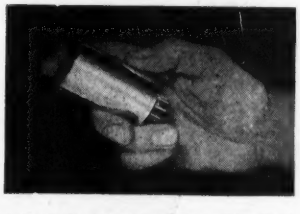

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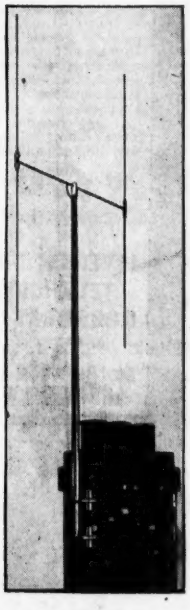

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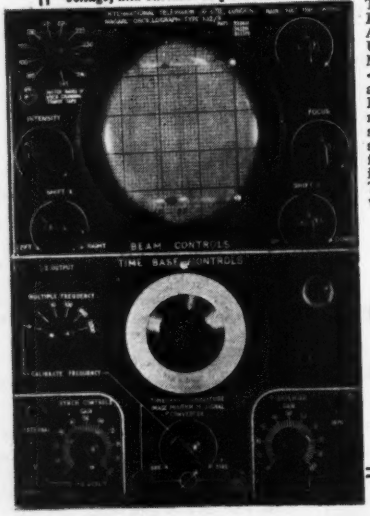

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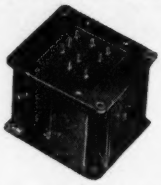

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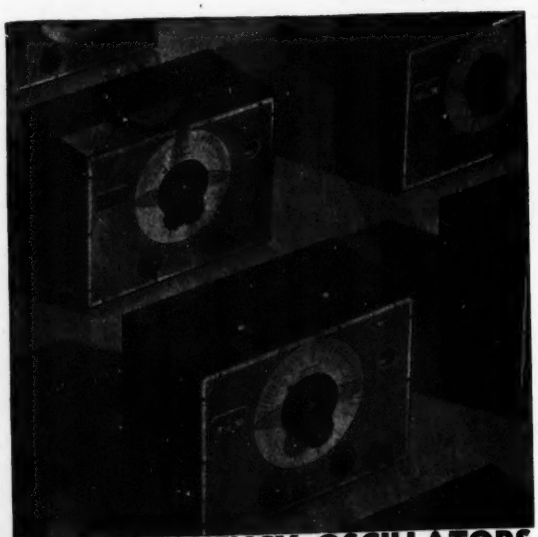

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JANUARY, 1947

Volume XIX. No. 227.

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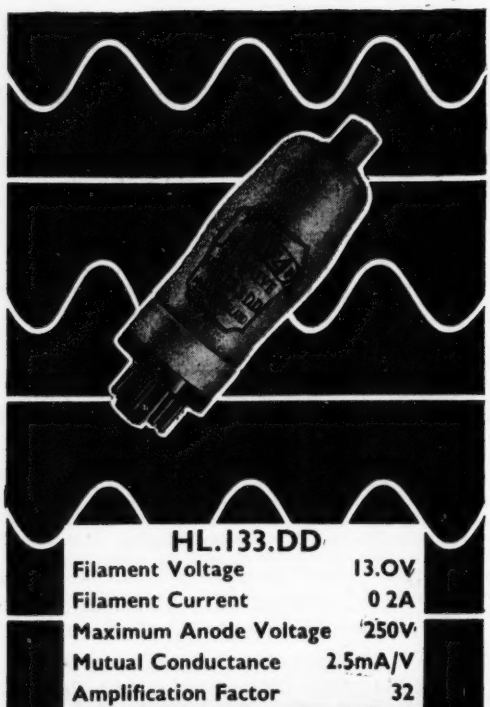

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Notice Board

New Volume

THIS issue commences a new volume of this Journal—No. XIX, and we are pleased to say that the recent small increase in the paper ration has enabled us to add a few pages to the issue each month and increase the number of copies printed.

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To all readers of this Journal the Editorial Staff send Best Wishes for a Happy and Prosperous 1947.

ELECTRONIC ENGINEERING MONOGRAPHS

The fourth Monograph in the series is now ready under the title :

The Gas-filled Triode and its Applications

By

G. WINDRED, A.M.I.E.E.

This subject is of interest to all industrial firms who have installed electronic apparatus and to those concerned in its operation and maintenance.

Copies can be obtained from Technical Booksellers, price 2s. 6d., or direct from the Circulation Dept. Hulton Press, 43 Shoe Lane, E.C.4. Price 2s. 8d. post free.

Binding

The publishers regret that it is still not possible to arrange for a standard uniform binding cover to be issued, and readers are recommended to wait until material and labour is more readily available.

A few binding covers for *Electronics, Television & Short Wave World*, as this journal was formerly called, are still available, price 2s. 3d. post free.

Contributions

Original contributions on all matters within the scope of this Journal are welcomed, and will be carefully considered.

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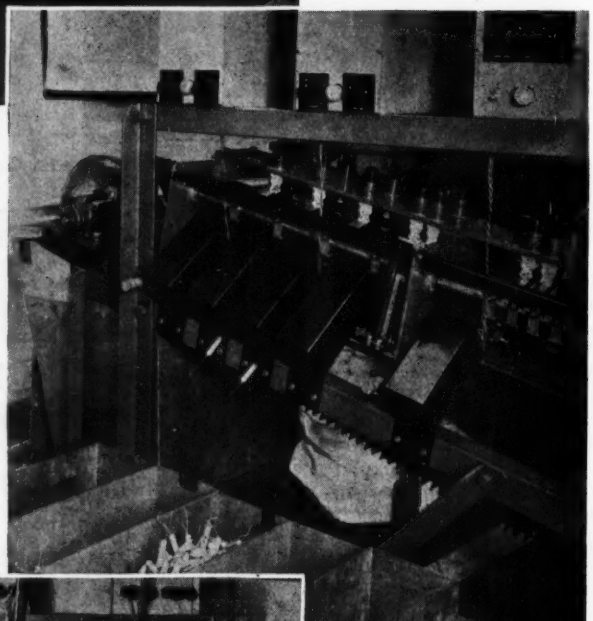


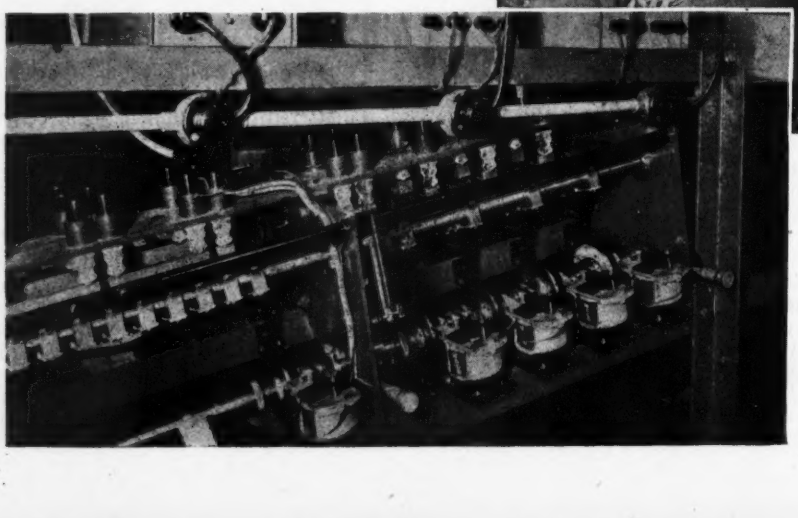


Fig. 1 (top left). Battery of Automatic Machines testing radio capacitors.

Fig. 2 (above). Chutes through which capacitors are delivered on final capacitance-value test.

Fig. 3 (left). Ejection Mechanism.

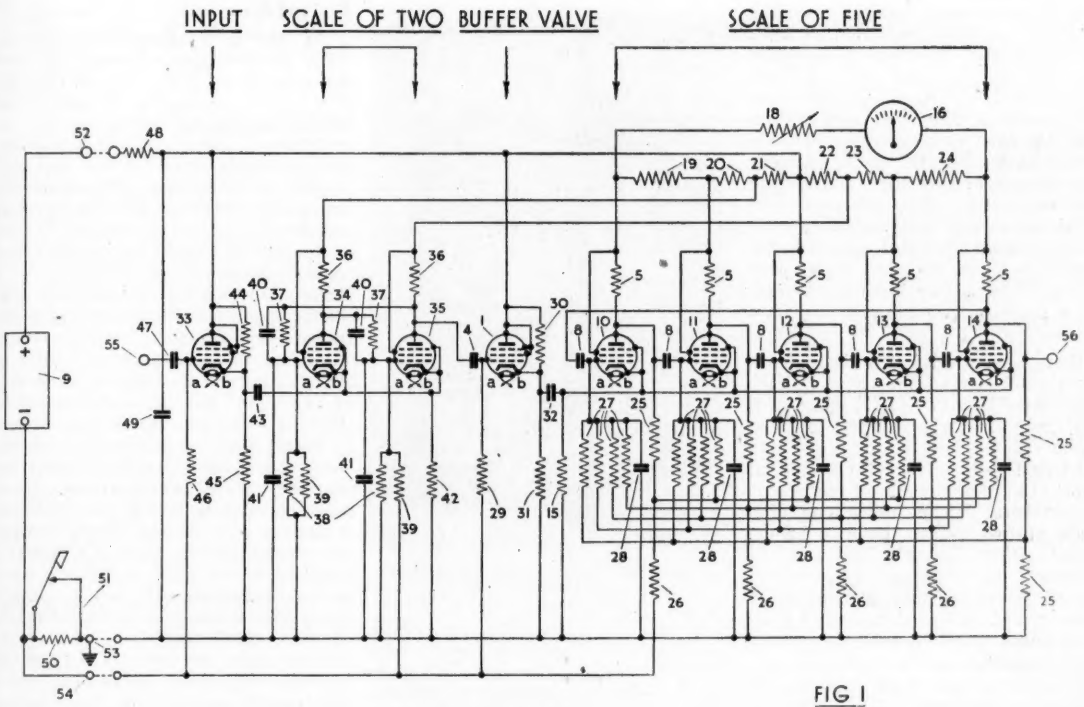


FIG 1

An Electronic Decimal Counter Chronometer

By S. S. WEST, M.B.E.*

A precision instrument designed to measure and indicate directly by means of dial readings time intervals to five significant figures. The first part of the article describes the operation of the scale-of-five circuit used.

ELECTRICAL counting circuits are known and have been used either alone or in conjunction with electro-magnetically operated mechanical counters for counting events occurring at speeds considerably greater than could be counted by a mechanical counter alone. One common use of a counter of this type is to count the number of electrical breakdowns in a gas due to ionization effects, the number of breakdowns in unit-time being then taken as a measure of the strength of the source of the ionization. Such events occur at random time intervals, some of which are of very short duration so that accurate counting requires a counter having a very rapid response and many counter circuits have been developed for this purpose. Another counter application of growing importance is the use of a high speed counter as an electrical chronometer for measuring short time intervals. For this purpose an oscillator of accurately known frequency is provided and the counter is used to count the number of cycles of oscillation which occur during the time interval to be measured.

A comprehensive investigation of this particular application for electrical counting circuits was carried out in the Development Department of Cinema-Television, Ltd., at the request of Woolwich Research Department and resulted in the development of a hard valve 'scale of ten' counting circuit.†

* Cinema-Television, Ltd.

† Br. Pat. No. 572,884 (T. C. Nuttall. Cinema-Television, Ltd.)

Choice of Scale Factor

Theoretically any number may be used for the scale factor, but the choice of a suitable scale factor can make a considerable difference to the convenience of using the counter and interpreting the numerical answer. Thus the ideal counter would operate on a 'scale of ten' basis so that where several stages are used the first stage would count units, the second stage in tens, the third stage in hundreds, etc. On the other hand, as an example of a bad choice of scale factor, if the scale factor was 3, then the significance of one count at each stage would be 1, 3, 9, 27, 81, 243, etc., which would obviously be most inconvenient for numerical purposes.

In the past the choice of a scale factor has been determined by the cir-

cuit arrangements available. The simplest counter stage operates with a ' scale of two ' and may be designed to use either gas-filled valves or hard vacuum valves. An arrangement of five gas-filled valves in ring formation has been proposed to produce a ' scale of five ' stage which, together with a scale of two stage, could form a scale of ten stage. However, gas-filled valves are not considered sufficiently reliable for high speed operation so that, in the past, high speed counters have always been constructed on a scale of two basis, using hard valves.

Using a scale of two throughout, the significance of one count at each stage would be 1, 2, 4, 8, 16, 32, 64, 128, 256, 512 for a counter counting up to 1023. There is no simple way of transforming from this scale of two to the normal scale of ten system of numbers. The indications of a scale of two counter have to be decoded either by calculation or by reference to a previously prepared set of tables. Either method is inconvenient and laborious and, further it is found in practice that there is a real possibility of human error introduced in the process of observing the indications and translating them into the numerical answer. These difficulties appear to be inherent in the scale of two counter or, indeed, in any scale other than a scale of ten.

It is necessary to include some means of indicating the results of the operation of counting. In principle this involves the indication of the circuit conditions obtaining at the end of the count. There are a number of methods of indicating circuit conditions, such as glow lamps, relays or milliammeters and the choice of method can materially affect the convenience and ease of using the counter. In connexion with scale of two counters small neon lamps have been used to indicate which of the two valves of each stage is operative. The information so indicated may then be decoded to arrive at the numerical answer. It has also been proposed to combine the indications of three or four consecutive stages of a scale of two counter on a so-called ' interpolating meter.' This method gives a direct reading up to 7 or 15 counts, but it is not possible to use several meters on consecutive groups of stages to give a direct reading of a large number of counts owing to the arithmetical nature of the scale of two principle. Moreover, the method hitherto proposed for operating the meter involves the use of additional interpolating valves. Such complications have been avoided in the circuits described herein and the operation of the various counter stages is arranged to indicate directly on a meter, the arrangement being such that no additional valves are employed.

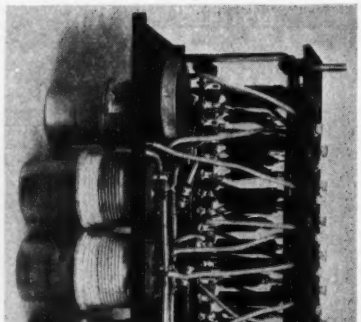


Fig. 2. Scale-of-ten unit with dust cover removed.

A circuit diagram, Fig. 1, shows the arrangement adopted for a scale of ten unit. The photograph of Fig. 2 shows the physical arrangement of the complete unit. Nine valves are used. Valves *34* and *35* comprise a scale of two circuit, valves *10, 11, 12, 13* and *14* forming a scale of five circuit. It is proposed to describe the scale of five circuit first.

Scale-of-five circuit

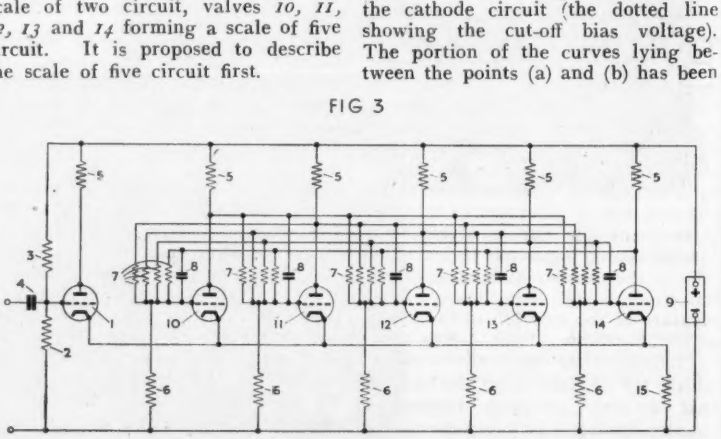
As seen in the simplified diagram, Fig. 3, the circuit comprises five counting valves, *10, 11, 12, 13, 14*, the anodes and grids of which are interconnected by means of the resistances *5, 6* and *7*, forming a potential dividing chain across the H.T. supply *9*. A condenser *8* is connected from each valve anode to the grid of the succeeding valve and all the cathodes are connected together and to the common bias resistance *15*. A buffer valve *1* has its cathode also connected to the common bias resistance and its anode to the H.T. positive line. The grid of this valve is biased by connexion to the resistances *3* and *2* so that the valve does not take current under normal conditions.

When the circuit is switched on, only one of the valves *10-14* will take current, since as soon as anode current starts to flow in one of the resistances *5* a portion of the voltage developed across this resistance is applied to the grids of all the other valves simultaneously, which voltage drop biases the grids of these valves beyond cut-off point.

It is quite fortuitous which of the valves *10-14* takes current first, but in the operation of setting the counter it is arranged that valve *10* is always conducting when the circuit is ready for use.

The stable receptive condition will be maintained until the application of an impulse to valve *1*. The action when such an impulse is applied can be studied with the aid of Fig. 4a, which gives a picture of the simultaneous voltage variations occurring in each of the five grid circuits and the cathode circuit (the dotted line showing the cut-off bias voltage). The portion of the curves lying between the points (a) and (b) has been

FIG 3



SIMPLIFIED SCALE OF FIVE CIRCUIT

expanded in time scale to show the action more clearly. If drawn to the correct scale the time interval (a)-(b) would be too small to show on the diagram.

Assume that the valve *10* is conducting and that an impulse is applied to the grid G_1 of valve *1*. At the start of the pulse valve *1* takes current and the cathode voltage rises (line C), the value of cut-off bias rising as well (dotted line). Note that the anode current starts when the pulse applied to G_1 raises its potential above the cut-off bias line at the point marked 'I_a starts,' in Fig. 4b.

The rise in cathode voltage causes valve *10* to take less current (marked 'start of cut-off of I_a' in Fig. 4c) and as the cut-off bias rises above the value of *G.10* grid potential the anode current in valve *10* ceases.

The reduction or interruption of current in valve *10* causes its anode voltage (not shown) to rise and so transmits a positive signal through a condenser *8* to *G.11*. The rise of voltage on *G.11* more than offsets the original rise of cathode voltage so that valve *11* takes current.

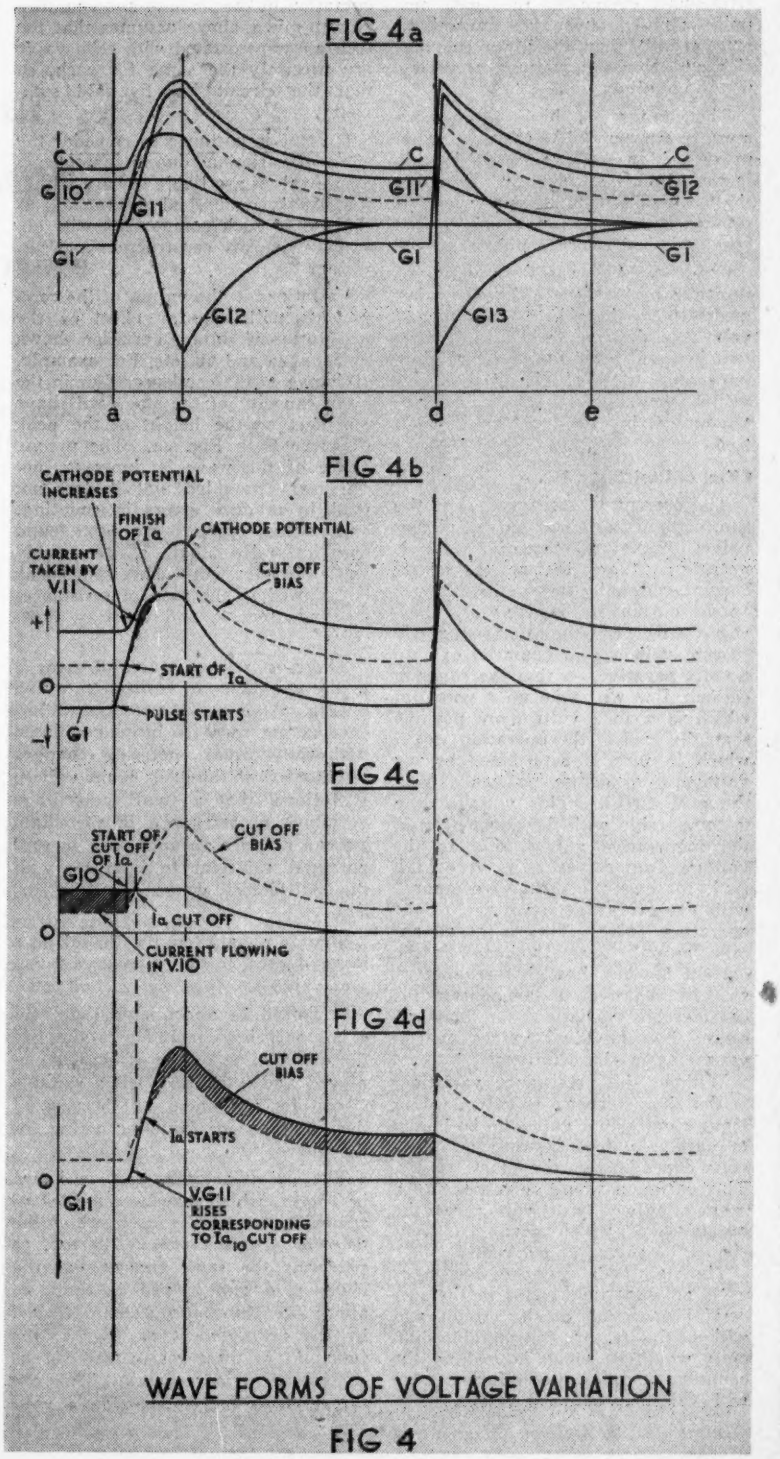
The current in valve *11* carries the cathode voltage still more positive so that valve *1* becomes inoperative. Thus in the interval (a)-(b) valve *10* has gone out of operation, valve *11* has come into operation, and valve *1* has been in operation only for a sufficient time to effect the changeover from valve *10* to valve *11*. Valve *1*, having completed its work, no longer requires the positive voltage on its grid, which returns to the datum potential.

At the time instant (b), valve *11* is in operation, but not quite under the same conditions as valve *10* was originally. However, in the time interval (b)-(c) the voltages slide to their correct new values so that in the interval (c)-(d) the circuit has attained its new condition of stability with valve *11* operative instead of valve *10*.

The detailed diagrams of Fig. 4b, (c) and (d) show the time intervals more clearly and the shaded portion in Fig. 4b corresponds to the time interval for which the potential of G_1 is above the cut-off point.

Action of Condenser 8

An essential condition for the successful operation of the circuit is that the interruption of the anode current of valve *10* shall cause an overswing in the potential of *G.11* (at the point (b) in the diagram) followed by the recovery between (b) and (c) to its normal value, at (c)-(d).



WAVE FORMS OF VOLTAGE VARIATION

FIG 4

This implies that the range of high frequencies composing the sharp impulse applied must be transmitted more readily than the lower frequencies and slow fluctuations occurring in the circuit.

This range of high frequencies must be transmitted to the next valve in the chain only, since it is this factor which determines which valve shall become conducting when a previously conducting valve has been switched off by a pulse.

Condenser *8* serves the purpose of transmitting the sharp impulses immediately to the grid of the adjacent valve to the one which is being switched off, as it offers negligible impedance to the higher frequencies while the lower frequencies are attenuated by the resistance chain *7, 6*.

Effect of Resistance 15

The current in resistance *15* is the sum of the cathode currents of all the valves, but since only one valve is operating at any instant, the actual current through it is the normal anode current of one valve. This valve will pass the required anode current with a grid potential of 2 to 4 volts negative, so that the common cathode line will take up a potential which is 2 to 4 volts more positive than the grid of the operating valve, which in turn is determined by the voltage drop across resistance *6* in the grid circuit. This voltage drop is comparable with the anode-drop of the inoperative valves, and so the voltage drop across *15* is very high (say, for example, 100 V) compared with the grid-cathode voltage of the operating valve. This is of advantage, as only a small change in the current flowing through resistance *15* will be required to compensate for considerable variations in bias required by individual valves due to variations in characteristic.

Without this, resistance variations in the characteristics of valves would require individual valves to be biased to various values between 2 and 4 volts depending on the characteristic. This variation would correspond to a range of only 99 to 101 volts across the resistance *15*, which means a current change of only ± 1 per cent.

The stabilising action of resistance *15* is an important factor in the successful operation of the circuit and without this feature considerable difficulty would be found in making the counter operate successfully, even with carefully matched valves.

The theoretical description of the operation of the scale-of-five counting circuit given above assumes that the resistances associated with each valve are precisely the same for each, so that the circuit has five-fold symmetry.

It is of importance to consider the effect of variations due to components whose values are liable to vary within the usual commercial tolerances, as the use of such components will obviously simplify construction and servicing.

Variations in the values of the components will have an effect on the waveforms of voltage variation shown in Figs. 4a and 4b, etc. For example, a change in the condenser *8* or in the stray capacity of the stage will have an effect on the height of the peak of curve C in Fig. 4a. The precise shape of the wave is, however, not important provided that it does not tend to produce errors in counting, and in this respect it has been found experimentally that a reasonably wide tolerance (say 10 per cent.) may be allowed in the case of resistances *5*, condensers *8*, and in stray capacities.

The most serious source of error is in the unbalance of resistances *7* and *6* (Fig. 3) since the potential difference across these is large compared with the normal operating changes of potential on the grids of the valves. It follows that a small percentage variation of resistance in the chain *7-6* can produce an unbalance in grid potential sufficient to interfere with the satisfactory working of the circuit.

Similar remarks apply, though to a lesser degree, to the resistances *2* and *3* of valve *1*.

It should be appreciated that Fig. 3 has only been included to simplify the explanation of the principles employed and is not in itself a suitable circuit for a counter unit because of the likelihood of faults occurring for the above mentioned reasons.

The circuit actually used is shown in Fig. 1, which may be regarded as a modification of Fig. 3, in which the network of resistances *5, 25, 26, 27* performs the same function as the chain *5, 6* and *7*, and in order to appreciate the improvement effected by the arrangement of Fig. 1, the functions of these resistances can be considered in more detail. They are threefold. First, to develop a voltage signal from the steady current passing through the valve, second, to divide this voltage approximately equally among the grids of the remaining valves in the counting circuit, third, to develop a backing-off voltage to compensate for the difference between the working potentials on the anodes and grids of the valves.

These three functions are performed in the above order in the circuit of Fig. 3, the resistances *5* developing the voltage signal which is distributed by resistances *7;* the potential divider action of *7* and *6* across the H.T. supply providing the necessary backing-off voltage across *7*.

In Fig. 1 the order of the functions is changed. Resistances *5* develop the voltage as before, then the potential divider action of resistances *25* and *26* develops the backing-off voltage across *25*, and finally the signal is distributed by resistances *27*.

In the original arrangement of Fig. 2, any error in the backing-off voltage due to unbalance in resistances *7* and *6* is applied directly to the grid of the valve. On the other hand, in the arrangement of Fig. 1 any error in backing-off voltage due to unbalance in *25* and *26* is attenuated in the subsequent distribution of the signal by the resistances *27*.

In both circuits there is an inevitable attenuation due to the distribution of the signal among the valves, but the important criterion is the ratio of useful signal to unbalanced backing-off voltage. The circuit of Fig. 1, by attenuating the backing-off errors in the same ratio as the useful signal, gives a more satisfactory condition and has much more latitude in resistance values than the simpler circuit of Fig. 3.

The function of the driver valve *1* (Fig. 3) has been described above. This valve takes a pulse of current of exceedingly short duration, and thus this pulse may be readily transmitted through a low capacity condenser.

Examination of Fig. 1 shows that the condenser *32* transmits the pulse, thus dispensing with the D.C. connexion of Fig. 3, and permits a more favourable arrangement for the bias of valve *1*. This is now obtained by the high resistances *30* and *31* which hold the cathode of valve *1* sufficiently positive to bias the valve just beyond the cut-off point. The use of the critical resistances *3* and *2* of Fig. 3 is thus avoided.

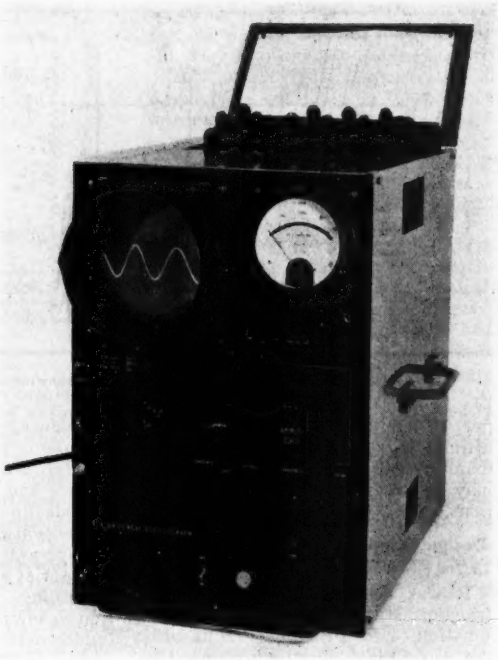
(To be continued)

A Universal Oscillograph

By G. L. HAMBURGER

A.M.I.E.E., A.M.Brit. I.R.E.

Part I. Factors affecting the design of a laboratory oscillograph. Discussion on power pack and linear time base circuits.



Front view of complete oscillograph with lid raised to show terminal panel.

THE universal value and importance of a good oscillograph in the laboratory is generally appreciated. In many cases special auxiliary apparatus is necessary for making visual the particular phenomenon to be investigated and it would, of course, be impossible to include, in a portable instrument, an array of all those auxiliary circuits for all conceivable purposes. However, one can make provisions at the instrument of such a nature that the oscillograph in itself offers a maximum of versatility and that the addition of auxiliary gear can be made as simple and easy as possible. An attempt has therefore been made to develop an oscillograph with a view to making it adaptable to its various purposes in the most convenient manner. Trace quality, convenience of a wide range of uses, and ease of operation stood in the foreground of the designing work.

The tube chosen was an easily available type, a hard tube with a 6-in. screen diameter. Since the oscillograph was mainly intended for visual work, a screen of green fluorescent colour was chosen.

It was considered useful to be able to vary the accelerating volts on the cathode ray tube, for it affords variation in deflection, sensitivity and brilliance.

A good saw-tooth time base of the self-running hard valve type was found best suited for universal applications. Contrary to the present fashion of expanded time base sweeps a direct sweep with 5 to 30 per cent. flyback and a repetition rate of from 0.5 to 275,000 c/s. was found advantageous. The expanded time base type has at higher sweep speeds the distinct disadvantage of lowering the brightness of the trace due to the scantiness of successive trace coverage, which in turn necessitates a higher beam current and accelerating voltage to make up for the lack of brightness, and results in poor focus quality and low deflection sensitivity. With the direct sweep the brightness and focus quality of a one megacycle wave and a 50 cycle wave, both picturing, say, 3 cycles across the screen, is naturally the same.

Further, an elliptical time base was incorporated which can be derived either from 50 c/s. mains or external frequencies up to about 60,000 c/s. Its applications are manifold and its uses range from harmonic analysis, especially the counting of harmonics, to pulse work where the absence of a flyback, *i.e.*, the observation of the total cycle, is often welcome.

A voltage calibration of the trace was included which is directly reading from 100 mV to 200 V for both A.C. and D.C., and which is inherently independent of the mains voltage and its fluctuations.

A frequency calibration method was adopted which enables the operator to calibrate adjustable audio frequencies up to about 10,000 c/s. in terms of mains frequency. These two latter features make the oscillograph a measuring instrument of great versatility.

Since the chosen cathode ray tube has, in the Y-direction, a deflection sensitivity of up to one millimetre per volt at quite satisfactory brightness and definition, a simple single stage was found sufficient for the deflection amplifier. Experience has shown that for special applications, for instance biological work, for television video frequencies, etc., one needs special types of amplifiers in any case, and it would therefore make the instrument unduly bulky to include an amplifier having a substantial gain and flat response from zero frequency to, say, five or ten megacycles.

A selector switch on the front panel enables the operator to change the type of operation, or synchronisation, etc., and quite generally it was endeavoured to perform such changes of operating condition by comprehensive switching actions.

Finally a retractable terminal panel at the top back of the oscillograph enables the user to establish the standard circuits for the four deflector plates, to connect up the ampli-

* Late of British Electrical Research Association.

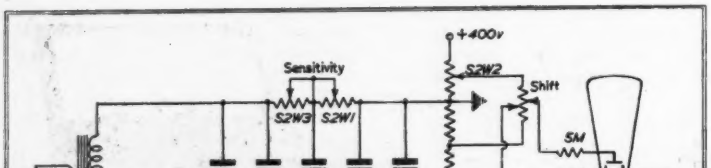


Fig. 1. General circuit diagram of power pack, showing sensitivity control.

fier, to modulate the beam, etc., and ultimately, to link up in an easy manner with any auxiliary gear that may be necessary for special applications. (See photograph.)

Design Details

2.1 The power pack

It was decided to use two mains transformers, one producing in conjunction with full-wave rectification the 450 V H.T. supply for time base and amplifier, and one providing with half-wave rectification the extra high tension (E.H.T.) for the cathode ray tube. It was realised that a generously designed compound H.T. and E.H.T. transformer would become unduly bulky. The smoothing circuits were generously equipped to guarantee a time deflection and trace brightness entirely free from 50 c/s. modulation, for nothing is more annoying than to have the trace of an alternative voltage of a frequency near *n*-times 50 c/s. perform longitudinal contractions and extensions due to undesired superimposed 50 c/s. modulation; rather is it desirable to be sure that if such an effect occurs it is really contained in the wave investigated, and not introduced by a poorly designed oscilloscope. Four 16 mfd. electrolytic capacitors and two chokes (10 and 20 Henries) were employed for H.T. smoothing. For the E.H.T., four 0.25 mfd. and one 0.5 mfd. capacitor of the jelly-filled paper type and series resistance dropping were used to produce a substantially smooth accelerating voltage. It must be borne in mind that the smoothing requirements for an oscilloscope cathode ray tube are more exacting when grid modulation of the beam is desired. Since with an oscilloscope tube the cathode is a few thousand volts negative with respect to earth, and since, on the other hand, the modulator grid is tied down to earth through a high voltage coupling condenser, any ripple voltage left on the cathode directly modulates the beam.

The variation of the accelerating voltage was effected by alteration of the series resistance in the E.H.T. smoothing chain. A simple calculation shows that for a smoothing ladder network of a given total series resistance R and a given number n of equal capacitors, the smoothing effect is a maximum if the total resistance R is broken up into n equal parts. A variation of accelerating voltage from 1,300 to 2,300 V call's for quite a substantial reduction of series resistance and because of the above observation it was decided to perform this reduction simultaneously in two stages instead of one. Fig. 1 shows the principle of the arrangement,, S_2W_1 and S_2W_3 being ganged sliders short-circuiting a portion of a series resistance; a slider movement in the direction of the arrow produces lower accelerating voltage V_a. The potentiometer current I was made to be substantially greater than the beam current so as to prevent the size of the trace from varying with the set brightness, *i.e.*, beam current. The shift or centring voltage applied through 5 megohm resistors to the X and Y deflector plates (covering a range ± 250 V with respect to earth) is derived from a potentiometer tapped to a portion of the negative E.H.T. potential divider and to a portion of the positive H.T., bleeder circuit. As it is desirable to keep the trace centred whatever the accelerating voltage, it was necessary to have the positive tapping point variable in the form of the slider S_2W_2, and also ganged to the other two sliders of S_1W_2 and S_2W_3. The permanent centring could have been achieved automatically by deriving that positive tapping point also from the E.H.T. voltage. This, however, would have involved the generation of a slightly higher E.H.T. voltage. Since the V_a variation is really performed in steps by means of a multiwafer type switch the addition of a third wafer was not considered unduly complicated, and was therefore adopted.

The heater of the cathode ray tube being at − 2,300 V with respect to earth, is fed by a specially insulated heater winding on the H.T. transformer.

2.2 The time base

As already mentioned, a self-running hard valve time base with continuously repeating sweep was chosen for this instrument. The Puckle time base[1] has become almost classical for this type of work and when properly designed can be made to operate up to repetition frequencies

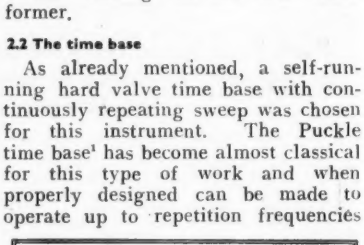


Fig. 2. Principle of circuit used for linear time base.

in the order of a quarter of a megacycle. Fig. 2 shows the fundamental principle of this circuit, and it can be recognised to be a multivibrator with two unstable conditions which is controlled by a capacity C and a resistance R in parallel, both serving as the timing element.

The resistance R is in practice always replaced by a pentode V_3 to ensure a constant, and therefore linear, rate of discharge of the capacitor C. However, it must be borne in mind that V_3 is a valve not essential for the actual operation of the circuit, it is merely a linearising agent. To reduce the circuit to its simplest mode Fig. 2 was drawn with the two valves V_4 and V_5 essential for operation.

In order to avoid misunderstanding with readers who are familiar with the original Puckle time base it must be emphasised at this juncture that capacitor C is, in the present circuit, connected to ground and — H.T. in-

stead of + H.T., as in Puckle's original circuit. This modification, though irrelevant as far as the fundamental principle of operation is concerned, has decisive advantages in the practical case as explained further on in connexion with the sawtooth amplifier.

Quite briefly the action is as follows: Assume the cathode of V_4 to be at the H.T. potential of + 400 V and the suppressor of V_5 at earth; then V_5 is fully conducting and its anode, due to the voltage drop across R_{100}, is at say + 200 V. V_4 is non-conducting since its grid is so much more negative than its cathode. The condenser C will discharge through the resistance R at a rate defined by the time constant RC, and the cathode potential of V_4 will fall steadily until it reaches a few volts above the V_4 grid potential. V_4 will begin to pass current which flows into the condenser C and will tend to charge it positively again. But the voltage drop across R_T, the anode load of V_4, will be transmitted to the suppressor of V_5, reducing the V_5 current, making the V_4 anode potential more positive. This in turn will increase the V_4 current which then, via R, C_{90} and R_{90} will further cut down the V_5 current, and so on. This cumulative process would occur instantly were it not for the charging of stray and interelectrode capacities which gives it a very short but finite duration. In any case the conductive state of V_4 will last until C is again charged up to almost + 400 V. Then also the anode voltage of V_4 will be back again at + 400 V for the lack of current, which (through C_{90} and R_{90}) has pulled the suppressor potential up to zero, making V_5 conductive, and the whole cycle can start all over again.

If higher and higher repetition frequencies are aimed at, the time constant RC must be made as small as possible as a first step. This is done by choosing very small condensers for C and by increasing the pentode current. As a next step the charging of C during the fly-back must be made correspondingly rapid, which calls for a high current triode V_4. Actually a triode-connected beam power tetrode KT66 was selected for the job. And finally the resistance R_{100} must be made as small as feasible to override the unwanted shunt capacities (interelectrode and stray capacities) which demands a high slope high current pentode for V_5. In this case two robust TSP4 television pentodes were chosen for V_3 and V_5.

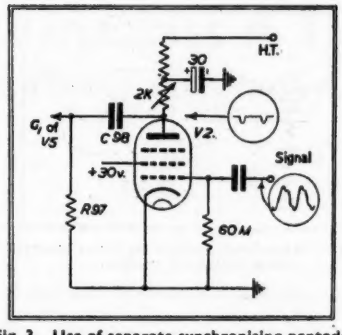


Fig. 3. Use of separate synchronising pentode in time base circuit.

Synchronising

The time base can be synchronised by applying a negative pip to the first grid of V_5, thus starting the rapid fly-back cycle which brings the condenser C potential to + 400 volts again. If, therefore, the speed of the time base—the rate of discharge of C through V_5—is set to such a value that the synchronising pip occurs just a short time interval before the fly-back cycle would naturally commence, the circuit will then run in synchronism with the impressed negative pips. It is essential for the synchronisation of multi-vibrators that the latter must always tend to run a little slower than the rate at which they are to be synchronised. If, therefore, in this case the time deflection goes from left to right on the screen of the cathode ray tube, the speed of the time base has to be adjusted such that without synchronisation the picture is slowly drifting to the left. Then it can be locked in by injecting this negative pip into the first grid of V_5.

Although one can achieve synchronisation by applying a suitably stepped-down portion of the signal voltage (on the Y-plate) to the first grid of V_5, this is not at all a satisfactory method. Slight changes of shape and magnitude of the signal would upset synchronisation, besides there would be locking difficulties at higher signal frequencies due to the necessarily high impedance potentiometer stepping down the signal.

Therefore a separate synchronising pentode V_2 was incorporated which, operating as a class C amplifier with extremely low screen voltage, only amplifies the uppermost (positive) tip of the signal applied to its control grid (see Fig. 3). These current pips occur as voltage pips with inverted polarity across the low and variable anode load R_{84} of V_2 and are fed via C_{88} to the grid of V_5. It is important to note in his connexion that the grid leak R_{87} of V_2 is a 60 megohm resistor and the coupling condenser C_{88} only 0.0001 mfd. This rather peculiar combination was adopted for preventing any, even the slightest noticeable deformation of the signal wave in the form of flattening its uppermost tips by the grid current of V_1, for it must be remembered that an automatic bias is produced by means of the diode action of the grid cathode portion of V_2 so that only the positive tip of the signal wave reaches cathode potential. The low screen voltage of about 30 V provides a short grid base of V_2, safeguards stable operation with so high a grid leak, and therefore ensures a pip-generation for relatively low signal amplitudes. Hence this scheme affords a safe and automatic synchronisation over a vast range of signal amplitudes from a few hundred volts to a few volts without any further adjustments by virtue of the limiter action of V_2.

A balanced sweep is essential to obtain good focus quality all along the trace from the extreme left to the extreme right of the screen. Since a falling saw tooth is produced across the capacitor C an overall unity amplification seemed to be the simplest way to obtain an inverted, *i.e.*, a rising saw tooth. The problem of stepping down the falling saw tooth before amplifying had been much discussed in literature (1), for it calls for an attenuation network with a flat response and zero phase distortion up to many megacycles. It must be added that the difficulty was aggravated by the fact that C was connected to + H.T. instead of ground in the original Puckle time base circuit.

In the present case the stepping down was very simply achieved by suitably subdividing the capacitor C. If this were done when C is connected to + H.T. the slightest variation in H.T. potential with respect to ground would appear amplified in the inverted saw tooth. This would inevitably cause hum modulation due to the mains ripples, and motorboating effects at low repetition frequencies. Putting a capacitor of magnitude three to four times C in series with C, as shown in Fig. 4, a reduced falling saw tooth will appear across the bigger capacitor. A grid leak must, of course, be provided, and its value chosen such that R_{108} times $3C$ is always substantially greater than the momentary repetition time of one saw tooth, a condition which is easily

satisfied by the value of 1 megohm for R_{108}. The amplification can be varied within a two-to-one range by varying the degree of cathode degeneration. As depicted in Fig. 4, a low voltage electrolytic capacitor C_{110} shorts a variable portion of the cathode resistance to ground as far as A.C. is concerned, whereas the D.C. bias conditions remain unaltered. This control R_{113} is brought out to the panel as a preset control, and called "balance," for it permits to set up a balanced time sweep so that the momentary potential midway between the two X-deflectors is always zero.

Since the saw tooth amplifier has to handle frequencies up to a few megacycles, the anode load has to be low. Actually 2,000 ohms were chosen for R_{117}. On the other hand, however, a substantial voltage swing has to be produced across those 2,000 ohms necessitating a high current swing; hence a beam power tetrode, again a KT66, was selected for the saw tooth amplifier.

In spite of the high anode impedance of the pentode V_3 the linearity of the primary saw tooth across C is not perfect because really an infinite impedance would be necessary to achieve it directly. L. H. Bedford has, however, shown a very ingenious and simple way (1) to obtain a practically perfect linearity (see Fig. 5a).

If C is to be discharged linearly, the discharging current I_a thought V_3 has to be constant. A glance at the pentode characteristic in Fig. 5b shows that a constant plate current at linearly falling plate voltage E_a demands a linearly rising grid voltage E_g (so that $\Delta E_a/\Delta E_g = \mu$) which in turn is provided by the feedback cathode resistance R_{FB} of V_5 since its grid is fed by the perfect linear saw tooth via the tapped time keeping condenser C. This linearisation circuit was incorporated in a slightly modified form in the complete circuit and can no doubt be easily recognised in the full circuit diagram given later. It is evident that one can overcompensate with this scheme. The feedback control R_{FB} appearing as R_{111} in the final circuit diagram is also brought out to the panel as a preset "linearity"-control.

The amplitude of the sweep can easily be controlled by varying the current through V_3 (see Fig. 2). This current determines the voltage drop across R_{100} and consequently the potential down to which the condenser C may be discharged through V_3. That current variation, and hence the sweep amplitude variation, was effected by varying the cathode potential of V_3 by means of R_{105} as can be seen from Fig. 6.

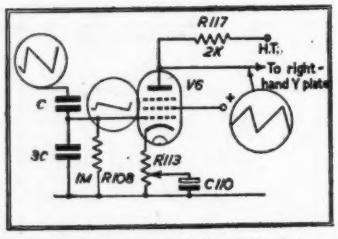


Fig. 4. Additional pentode for giving balanced sweep deflecting voltage.

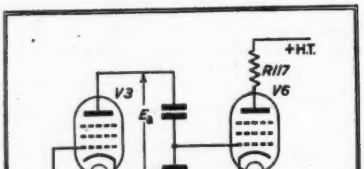


Fig. 5a. Bedford's circuit for giving improved linearity.

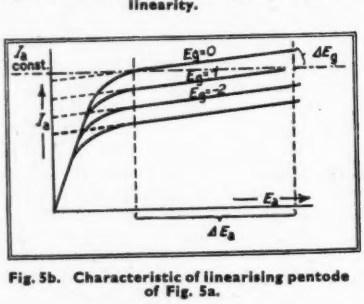


Fig. 5b. Characteristic of linearising pentode of Fig. 5a.

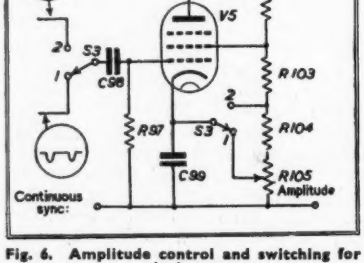


Fig. 6. Amplitude control and switching for single sweep.

The speed variation covering repetition frequencies from 0.5 to 275,000 c/s. can be carried out in three stages: coarse, fine and superfine. The coarse control is done by varying the capacitor C in steps by means of a three-wafer multistud switch as shown later: one wafer to vary the total capacity, one to obtain the stepped down saw-tooth for the amplifier, and a third to increase the total capacity for the lowest speed range without necessitating the use of a 10 μfd. paper condenser for the saw tooth potential divider. The fine control R_{94} amply covers the frequency range between the steps of the coarse control by varying the screen voltage of the discharging pentode V_3; its frequency range amounts to a ratio of about six to one. The superfine control R_{93} is a variable small resistor in series with the screen supply. It was found advantageous to make the trigger resistance R_T of Fig. 2 variable for different settings of the fine-speed control since it was desired to keep the flyback as short as possible for all settings of this fine-speed control R_{94}. Ultimately the trigger resistance was ganged with this control (see R_{80} and R_{94} of the full circuit diagram).

At very low repetition frequencies an unpleasant motorboating effect was at first experienced which was due to an interaction between saw tooth amplifier V_6 and saw tooth generator V_3, V_4 and V_5 via the powerpack. Decoupling the saw-tooth generator from the amplifier by means of a 2,000 ohm resistor R_{87} and another 16 μF. electrolytic capacitor C_{170} completely cured this effect.

The possibility of single stroke sweeps had, of course, to be included in a universal instrument. It is of fundamental importance for this type of operation that the stroke has to start with the main sweep, and not with the flyback, otherwise important information about the beginning of the phenomenon to be investigated would be lost or grossly distorted. This condition was put into practice in the following way. By setting the switch S_3 to "single stroke" (position 2), the cathode of V_5 was given a constant positive potential of 10 V which completely cut off the current of V_5 (see Fig. 6). This brings its anode to + H.T. potential and keeps the capacitor C continuously charged up at + H.T. potential through V_4. If now a positive pulse of a certain duration T is applied to the first grid of V_5, the whole time base becomes quite normally free running for the duration of T, and—most important—it has started off with the main sweep. It stops operating after the time T has elapsed and the capacitor C re-

(*Continued on page 22*)

Load Conditions in Class A Triode Amplifiers

By H. G. FOSTER, B.Sc.(Eng)., A.M.I.E.E.*

THE principles governing the correct choice of load resistance R_L for a triode power amplifier of A.C. resistance r_a working under Class A conditions have long been established, and in general there are two main classifications which determine the correct ratio of R_L/r_a for optimum power dissipation in the load.

These two classifications may be stated as follows:—

Case 1. If the input signal voltage to the valve is fixed it has been shown[1] that optimum power is obtained when the load resistance R_L is made equal to the A.C. resistance r_a.

Case 2. If the input signal voltage is limited so that the instantaneous grid potential is never positive, or so negative that the anode current falls below a prescribed minimum value, then optimum power is obtained when $R_L = 2r_a$,[2], assuming that the quiescent anode dissipation is adequate.

This value of load resistance is generally regarded as representing maximum power conditions for a triode working as a Class A amplifier, and results in a theoretical anode efficiency of 25 per cent.[3].

Nottingham[4] has, however, suggested that if the quiescent anode dissipation is specified and the grid voltage is limited only by a prescribed minimum anode current, then the optimum load may be several times the A.C. resistance of the value.

Under these conditions, and with no limitations placed on the anode voltage, the optimum value of R_L may be as high as twenty times to thirty times r_a and is obtained from the expression:—

$$R_L = 2r_a + \frac{P_Q}{I_Q^2} \quad \ldots\ldots\ldots\ldots (1)$$

where P_Q = specified maximum quiescent anode dissipation.

I_Q = quiescent anode current.

If the quiescent anode voltage is specified, a lower value of R_L of about eight times r_a results and is obtained from the expression:—

$$R_L = \frac{E_Q - e_{a\min}}{I_Q - i_{a\min}} = \frac{E - r_a(2I_Q - i_{a\min}) - \epsilon}{I_Q - i_{a\min}} \quad \ldots (2)$$

where E_Q = specified quiescent anode voltage.

$e_{a\min}$ = minimum anode voltage.

$i_{a\min}$ = prescribed minimum total anode current.

ϵ = intercept on the voltage axis of the extrapolated static anode characteristic for zero grid bias.

Nottingham has worked out a table of comparison for a triode with a maximum quiescent anode dissipation of 100 watts and shows that when Equation 1 is evaluated, the load resistance is 24.4 times the A.C. resistance of the particular triode, resulting in a power of 35.3 watts in the load. For a limited quiescent anode voltage the value of R_L is 7.65 times r_a as obtained by Equation (2) with a corresponding power of 31.9 watts, whereas when R_L is made equal to, and twice r_a, the power dissipations are 13.3 and 20 watts respectively.

Analysis of Ideal Triode

The foregoing analysis of the conditions for maximum power in a triode amplifier is similar to that of Nottingham, and is based on the supposition that the instantaneous anode dissipation never exceeds the maximum safe anode dissipation of the valve, and that no limitations are placed on the quiescent anode voltage. Since the valve is assumed to be ideal, the grid voltage will be allowed to vary between the limiting values of zero and cut off.

Under these conditions it will be shown that for the idealised triode there is no optimum value for the load resistance R_L, in which the power dissipated is a maximum, but that the power increases with increase of load resistance, and in the limit is equal to half the maximum safe anode dissipation of the valve itself. Since the power supplied to the anode with a high value of load resistance is very nearly equal to the maximum safe anode dissipation, the anode efficiency will approach 50 per cent. when the triode is working as a Class A amplifier.

Class A Amplifier

The results obtained with a practical triode will fall short of the ideal since the load resistance and supply voltage cannot be increased indefinitely, and a limiting value of R_L is given.

If the power triode is idealised and assumed to be linear over the working portion of its anode characteristics, then (for equal increments of grid voltage) the anode characteristics can be represented by a series of parallel, equally spaced lines, of which only the anode characteristic for zero grid voltage is shown in Fig. 1.

This characteristic will be represented by the straight line OA of slope $m_1 = \frac{1}{r_a}$ drawn from the origin, while the maximum anode dissipation of the valve will be represented by a rectangular hyperbola.

Now for any given load line, the power in the load will be increased as the load line is moved from the origin towards the right, and if during the excursions of voltage and current along the load line the instantaneous anode dissipation is not to exceed the maximum safe anode dissipation, the limiting condition will be reached when the load line is tangential to the line of maximum anode dissipation. If the load line is moved beyond this limit, then during a period of the operating cycle the maximum safe anode dissipation will be exceeded, although this is permissible in certain circumstances. But in general it can be stated that for any given value of R_L maximum conditions can be represented by a load line having a negative slope of $-\frac{1}{R_L}$ drawn tangential to the hyperbola.

It will be seen that if the load line is always tangential to the hyperbola the load line will be vertical and will coincide with the current axis when R_L is zero, while if R_L is infinity, the load line is horizontal and coincides with the voltage axis. Now if the hyperbola is represented by the general equation:—

$$xy = k \quad \ldots\ldots\ldots\ldots (3)$$

the anode characteristic for zero grid bias by

$$y = m_1 x \quad \ldots\ldots\ldots\ldots (4)$$

and the load line by

$$y = -mx + C \quad \ldots\ldots\ldots\ldots (5)$$

then at the point where the load line

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is tangential to the hyperbola we may write

$(-mx + C)x = k$ ..... (6)

where m_1 = slope of the line OA (anode characteristic for zero grid bias).

$-m$ = slope of the load line.

k = maximum safe anode dissipation of the valve.

so that from (6)

$$x = \frac{-C \pm \sqrt{C^2 - 4km}}{-2m} \quad \text{..... (6a)}$$

Now the condition for the load line to be tangential is that the roots of the above equation shall be equal, from which it follows that the discriminant shall be zero or that

$C^2 = 4km$ ..... (7)

If the term under the radical is positive, there will be two roots implying that the load line will cut the hyperbola at two points and that the maximum safe anode dissipation will be exceeded during a portion of the operating cycle, while if the term under the radical is negative, the roots will be imaginary, the load line will not touch the line of maximum anode dissipation, and the valve will not be working under its maximum conditions.

A point of interest is the case when R_L is made equal to r_a. When this is so, the slopes of the anode characteristic for zero grid bias and of the load line are equal and opposite, and the point P of the intersection of these two lines coincides with the point A of intersection of the anode characteristic and the hyperbola. Moreover, the load line is tangential to the hyperbola at the point of coincidence.

From this it follows that if R_L is made less than r_a the point at which the load line is tangential to the hyperbola will occur to the left of, and above the anode characteristics for zero bias, while if R_L is made greater than r_a the point at which the load line is tangential will be to the right of, and below, the anode characteristic for zero bias. It can be seen by inspection that when R_L is less than r_a, greater power could be obtained by drawing the corresponding load line not tangential to the hyperbola but through the point A, but even so the power will be less than when R_L is made equal to r_a. Since the condition that R_L is less than r_a does not generally obtain in practice it will be disregarded and the analysis confined to the case where R_L is always greater than r_a.

Let P be the point of intersection of the anode characteristic for zero bias and the load line, when

$y = m_1x = -mx + C$ from which

$$x = \frac{C}{m_1 + m} \quad \text{..... (8)}$$

$$y = \frac{m_1C}{m_1 + m} \quad \text{..... (9)}$$

Now PS = y and SR = $\frac{y}{m}$, so that the area of the triangle PSR is:—

$\frac{1}{2m}\left(\frac{m_1C}{m_1 + m}\right)^2$ and on substituting the value of C^2 obtained in (7) the area triangle PSR becomes:—

$$\frac{2km_1^2}{(m_1 + m)^2} \quad \text{..... (10)}$$

Now the power dissipated in the load is

$$\left(\frac{\text{Peak to peak current}}{2\sqrt{2}}\right)\left(\frac{\text{Peak to peak volts}}{2\sqrt{2}}\right)$$

$$= \frac{PS}{2\sqrt{2}} \times \frac{SR}{2\sqrt{2}}$$

$= \frac{1}{4} \times$ area of Δ PSR.

$$= \frac{km_1^2}{2(m_1 + m)^2} \text{ watts} \quad \text{..... (10a)}$$

Inspection of this equation shows that since m is the only variable, there is no optimum value which makes the power a maximum, but the power increases as m is decreased.

Thus the theoretical maximum power is obtained as $m \to 0$ or as $R_L \to \infty$ and in the limit the maximum value is

$\frac{k}{2}$ watts ..... (10b)

which is half the maximum safe anode dissipation of the valve itself.

Power Supply to the Anode

With an idealised triode there will be no second harmonic distortion due to the non-linearity of the valves' characteristics so that the quiescent point Q will be located at the mid-point of the load line PR and the product of the coordinates of Q will be the power supplied to the valve.

Now the current coordinate is QU, which by similarity is $\frac{y}{2}$, so that the quiescent current I is:—

$$\frac{m_1C}{2(m_1 + m)} \quad \text{..... (11)}$$

Fig. 1. Static characteristics of idealised triode with load line tangential to curve of maximum safe anode dissipation.

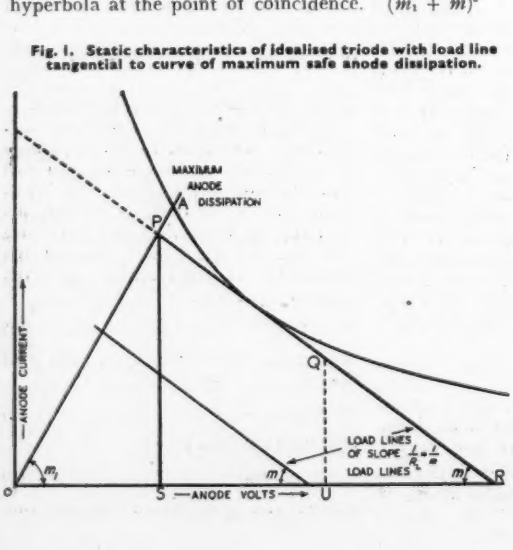
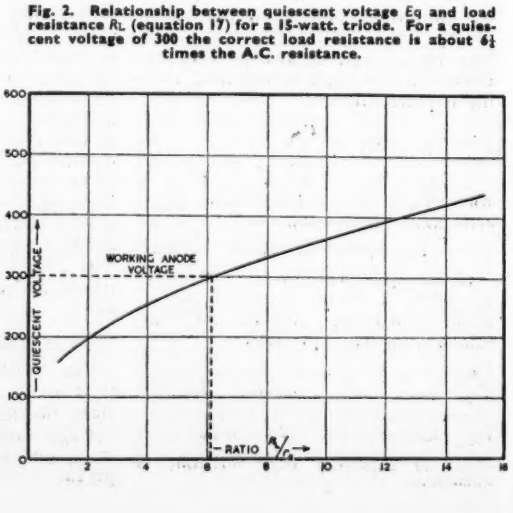


Fig. 2. Relationship between quiescent voltage E_Q and load resistance R_L (equation 17) for a 15-watt. triode. For a quiescent voltage of 300 the correct load resistance is about 6½ times the A.C. resistance.



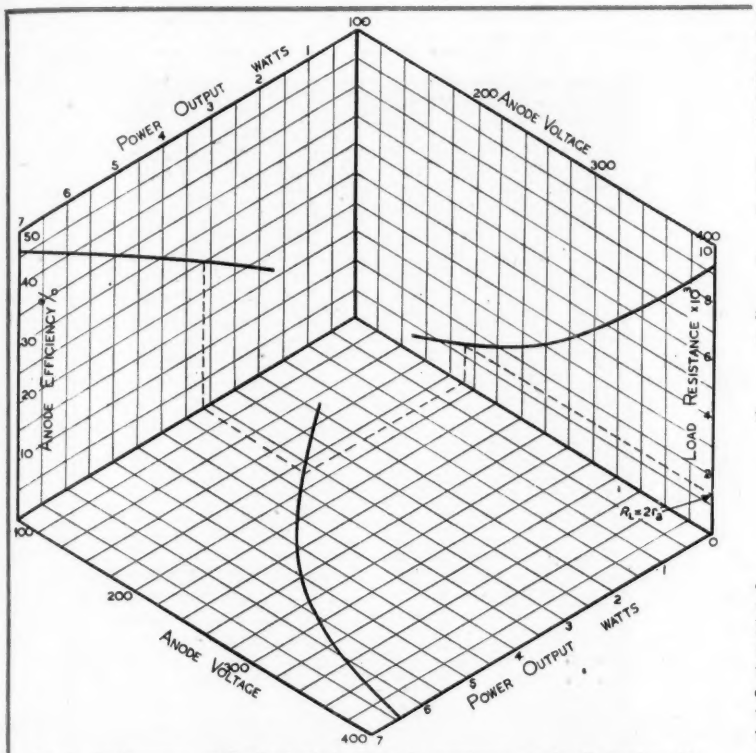


Fig. 3. Performance of idealised triode Type A, maximum anode dissipation = 15 watts. A.C. resistance = 730 ohms. Normal working voltage = 300.

while the voltage coordinate, OU is

$$\frac{y}{m_1} + \frac{y}{2m}$$

and the quiescent voltage E_Q is :—

$$\frac{y(2m + m_1)}{2m_1 m} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Hence the power supplied to the anode is

$$\left(\frac{m_1 C}{m_1 + m}\right)^2 \cdot \frac{m_1 + 2m}{4m_1 m}$$

and substituting the value of C obtained in (7)

D.C. power supplied to the anode

$$= \frac{k m_1^{2\cdot}}{(m_1 + m)^2} \cdot \frac{m_1 + 2m}{m_1} \text{ watts} \quad (13)$$

The anode efficiency is therefore

$$\frac{\text{Power dissipated in load}}{\text{D.C. Power supplied to anode}} = \frac{\text{equation 10a}}{\text{equation 13}}$$

$$= \frac{m_1}{2(m_1 + 2m)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

It is seen from the above expression that when R_L is made equal to r_a ($m = m_1$) the resulting anode efficiency is 16.7 per cent. and that the efficiency will increase with increase of load resistance.

As $R_L \to \infty$, $m \to 0$, and in the limit the theoretical anode efficiency will approach its maximum of 50 per cent.

This expression for anode efficiency is similar to that given by Terman[5] for the ideal anode efficiency as :—

$$\frac{R_L}{2(R_L + 2r_a)}$$

and if R_L is made equal to $2r_a$, the anode efficiency as obtained by both of these expressions is 25 per cent., which is quoted as theoretical efficiency of a valve operating under conditions of maximum power output with Class A operation and a prescribed quiescent anode voltage[7].

Limitations of Anode Voltage

From the above it has been established that for the idealised triode, the power developed in the load approaches half the maximum safe anode dissipation of the valve when the load resistance is very high, in which circumstances the anode efficiency approaches 50 per cent., and this assumes that no limitations are imposed on either the quiescent anode voltage or the peak anode voltage.

If the maximum peak anode voltage is specified, the limiting value of load resistance can be readily obtained, and referring to Fig. 1 we may write :

$$OR^2 = e_{a^2 max} = \frac{C^2}{m^2}$$

and substituting for C from Equation (7)

$$e^2_{a max} = 4k/m$$

from which $$m = \frac{4k}{e_{a^2 max}} \quad \ldots\ldots\ldots\ldots \quad (15)$$

or Maximum load resistance =

$$\frac{(\text{Specified maximum Peak Anode Voltage})_2}{4 \times (\text{maximum Safe Anode Dissipation}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

The relationship between the quiescent anode voltage in terms of the valve characteristics and the anode load has already been given by Equation (12) and if the load is connected to the anode circuit by means of an output transformer, the primary of which has negligible resistance, then the quiescent anode voltage can be assumed to be equal to the anode supply voltage.

Now the quiescent anode voltage has been given by Equation (12) as

$$E_Q = \frac{y(m_1 + 2m)}{2m_1 m}$$

and on substituting the value of y obtained in Equation (9)

$$E_Q = \left(\frac{m_1 C}{m_1 + m}\right)\left(\frac{m_1 + 2m}{2m_1 m}\right)$$

If C is eliminated we may write :—

Quiescent anode voltage E_Q = Supply Voltage

$$= \sqrt{\frac{k}{m}} \cdot \frac{m_1 + 2m}{m_1 + m} \quad \ldots\ldots\ldots\ldots \quad (17)$$

so that the supply voltage for any given load can be obtained.

But normally it is the anode supply voltage which is given, and it is required to find the load which will have its load line tangential to the line of maximum anode dissipation, and its quiescent voltage equal to the supply voltage.

If the load resistance is evaluated in terms of the supply voltage, and

the valve constants from Equation (17), the resulting expression is cubic in form and is not amenable to solution, but the correct load can be readily obtained by plotting the relationship between the quiescent anode voltage E_Q and anode load R_L for a given triode and interpolating as shown in Fig. 2.

Comparison of Idealised and Practical Triode

The performance of the idealised triode as obtained by this analysis is shown in Fig. 3, which relates to a typical low power triode of the 15 watt class, and comparison with the performance of the practical triode as obtained by the usual graphical methods shows that agreement is reasonably close.

Inspection of Fig. 3 shows that an improvement in both power and efficiency can be expected with a load resistance greater than twice the A.C. resistance, together with a reduction of second harmonic distortion.

With an unlimited anode supply voltage about 80 per cent. of the theoretical maximum power output is obtainable with a load resistance of between eight and nine times r_a. Higher load resistances than this do not yield a worth while increase of power output and may lead to peak anode voltages beyond the capabilities of the valve.

The correct choice of load resistance depends on the characteristics of the valve and can be obtained if either the maximum working or maximum peak anode voltage is known. For the triodes given in Table 1 the load varies from about three to twelve times the A.C. resistance of the valve.

It should be noted that the predicted quiescent voltage is less than the actual value, and that for load resistances higher than about twice the A.C. resistance, the difference between the predicted and actual values is substantially constant and equal to the intercept ϵ on the voltage axis of the extrapolated anode characteristic as given by Nottingham.

As is to be expected, the actual power output is less than that of the idealised triode, but the method given herein enables the performance of the valve to be predicted with a reasonable degree of accuracy, and it has the merit of simplicity.

Application to Push-Pull Amplifier

The previous analysis of the single ended triode can be extended to cover the necessary conditions for idealised triodes operating in push-pull and working under Class A conditions.

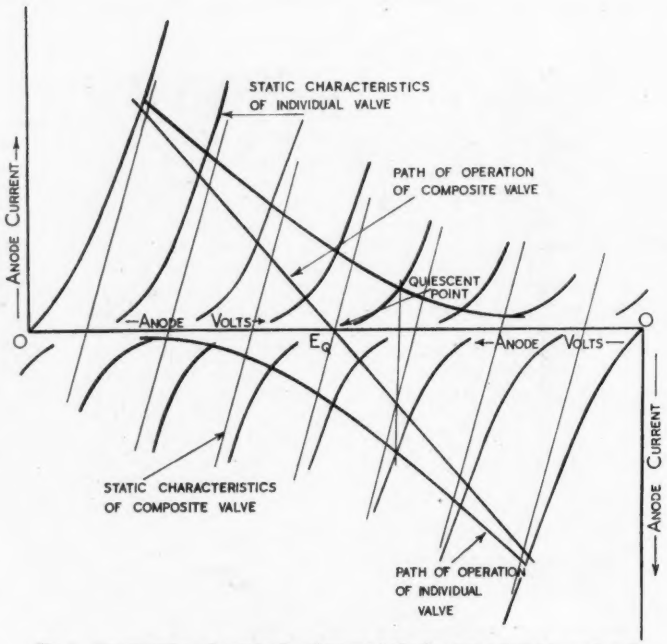


Fig. 4. Construction of composite characteristics for two triodes in push pull using B.J. Thompson's method.

A graphical analysis of the separate triodes in push pull is difficult because of the coupling between the separate anode circuits through the output transformer, but if the triodes are replaced by their equivalent composite valve a graphical representation of the conditions is readily obtainable, to which the preceding methods can be applied.

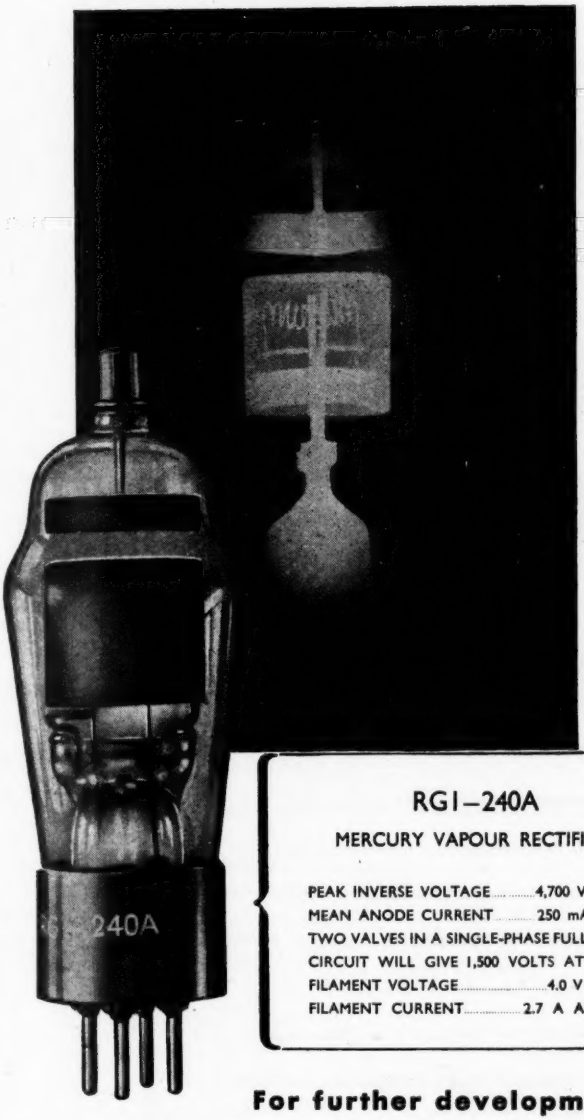
The "equivalent composite triode"[7] is defined as the triode "which, working into one half of the primary winding of the output transformer, with the other half open-circuited, produces the same current and power in the load as would the two triodes in push pull."

The method of obtaining the anode characteristic of the composite triode is due to B. J. Thompson[8] and consists in plotting the anode characteristics of the individual valves in the ordinary way, and rotating the family of characteristics for one valve through 180° about the origin. One set of characteristics is then moved along the voltage axis until the operating voltages on the two scales coincide, or, in other words, until the distance between the origins is *twice* the operating voltage.

The composite characteristics are obtained by adding algebraically the anode characteristics of the two plots for corresponding grid voltages, and, if the two valves are assumed to be both identical and ideal, then the composite characteristics for equal increments of grid voltage will consist of a series of equally spaced parallel lines, as shown in Fig. 4, and the path of operation of the composite valve will be a straight line of negative slope of $\frac{1}{R_L}$ corresponding to an effective anode to anode load of $4R_L$ ohms, and drawn through the operating point.

In the following analysis, it will again be assumed that the instantaneous power will not be allowed to exceed the maximum safe anode dissipation, and this condition will be met by drawing the load line, or the path of operation of the composite valve tangential to the line of maximum anode dissipation.

It will be seen that since the load line is to be tangential to the lines of maximum anode dissipation of the separate valves, the distance between the origins of the separate anode characteristics must be specified, and for any given quiescent or operating voltage there is only one load line which can be drawn to meet these requirements.



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The path of operation of the individual valve is obtained by the reverse of the process by which the composite characteristics were constructed, and consists in drawing a vertical line through the intersection of the load line with the composite characteristics for a specific value of grid bias.

The intersection of this vertical line with the associated anode characteristics of the individual valves gives their operating point for that specific value of grid bias, and if this process is repeated at similar points of intersection along the load line, the complete paths of operation for the individual valves can be obtained.

The valves will again be assumed to be working under Class A conditions, which implies that the individual anode currents do not fall to zero when the path of operation of the composite valve is restricted by the individual anode characteristics for zero grid bias. The correct slope of load line can be determined by reference to Fig. 5, which shows the load line drawn tangential to the individual lines of maximum safe anode dissipation; OA and O_1A_1 being the anode characteristics for zero grid bias.

Choice of Load Resistance and Supply Voltage,

The correct load resistance for a specified supply voltage and alternatively the correct supply voltage for a specified load resistance can be obtained by reference to Fig. 5.

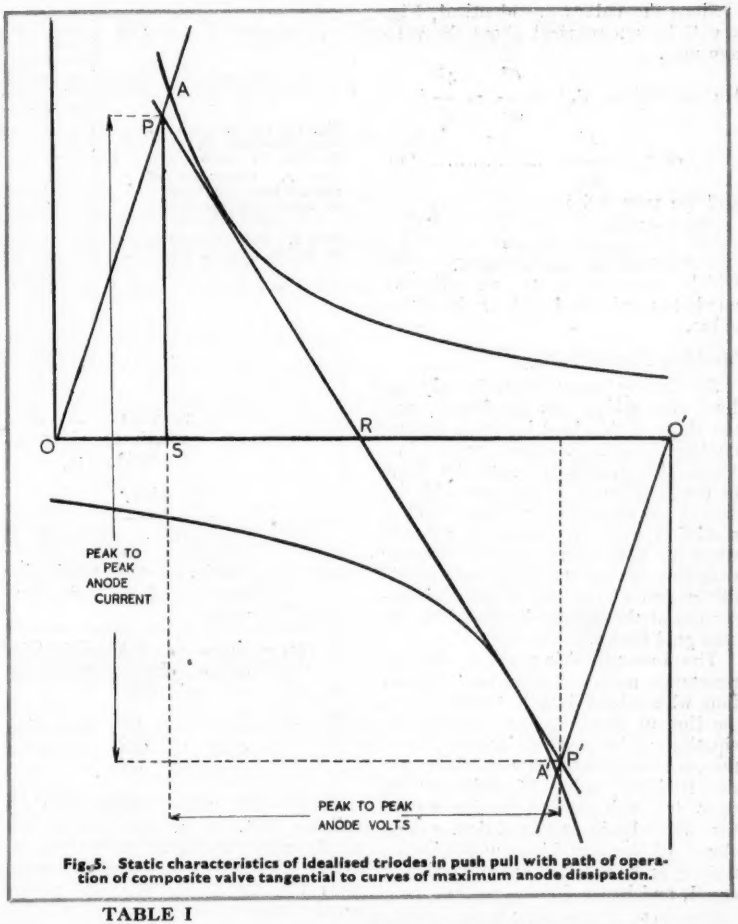

Fig. 5. Static characteristics of idealised triodes in push pull with path of operation of composite valve tangential to curves of maximum anode dissipation.

TABLE I

Type Valve	MANUFACTURER'S RATINGS							IDEALISED PERFORMANCE WITH GIVEN ANODE SUPPLY VOLTAGE				
	Anode Dissipation Watts	A.C. Resistance Ohms	Optimum Load Ohms	Estimated Power Output Watts	Working Anode Voltage	Input Power Watts	Anode Efficiency %	Load Resistance Ohms	Power Output Watts	Anode Efficiency %	Ratio R_L/r_a	Peak Anode Volts / Anode Supply Volts
B	15	1200	2750①	2.65	250	10.5	25.2	2300	3.24	24.5	1.92	1.49
		1150	2200②	2.75	250	12.5	22					
		1200	3000③	4.2	300(max)	14.4	29.2	3950	4.38	31.2	3.29	1.62
C	25	1200	2700③	5.85	400(max)	25	23.4	4000	6.6	28.6	3.3	1.58
D	25	1265	3200③	5.5	400(max)	25	22	4200	7.3	31.1	3.3	1.62
E	30	580	4500①	8.0	400	25	32	4250	11.6	39.3	7.35	1.79
			6000④	11.0	500(max)	30	36.7	7100	12.8	43	12.3	1.85
F	100	1410	6800④	30	1000(max)	100	30	7400	35.4	36.2	5.25	1.72
G	250	2290	17,500④	90	2500(max)	250	36	20,600	101	40.8	9.0	1.82

NOTE.—1. Valve is being being operated below its maximum and corresponding load line does not touch the line of maximum anode dissipation.
2. Load line tangential to line of maximum anode dissipation but anode supply voltage is below maximum.
3. Load line crosses line of maximum anode dissipation so that instantaneous anode dissipation will exceed maximum safe anode dissipation over a portion of the operating cycle.
4. Corresponding load line is tangential to line of maximum anode dissipation and quiescent anode voltage is equal to the maximum recommended supply.

Since the valves are identical, Fig. 5 will be symmetrical about the voltage axis.

$$\text{Hence } OR^2 = E_Q^2 = \frac{C^2}{m^2} = \frac{4k}{m}$$

$$\text{or } m = \frac{4k}{E_Q^2} \quad \ldots\ldots\ldots\ldots (20)$$

and we may write

$$\text{Load resistance} = \frac{(\text{Operating voltage})^2}{4 \times \text{max. safe anode dissipation.}} \quad (21)$$

which corresponds to an effective anode-to-anode load of four times this value.

Limiting Anode Voltage

As already stated, there is only one load line which can be drawn, and the slope of this load line will depend on the distance between the origins. From this it follows that the slope of the load line will increase with decrease of operating voltage, and a condition will eventually be reached when the point of tangency will occur with the line of maximum safe anode dissipation above the point of intersection of the anode characteristic for zero grid bias.

The lower limiting value of load resistance may therefore be taken as that whose load line is tangential to the line of maximum safe anode dissipation at the point of intersection of the zero bias anode characteristic and the limiting value of quiescent or operating voltage can be determined for the limiting condition. The slopes of the zero bias anode characteristic and load line are numerically equal, and hence from Equation (20):

$$E_Q^2 = \frac{4k}{m_1} \quad \ldots\ldots\ldots\ldots (22)$$

or Limiting anode voltage =

$$\sqrt{\frac{4k}{m_1}} \quad \ldots\ldots\ldots\ldots (23)$$

Power Output

The power output of the equivalent composite valve can be calculated from the expression already given:—

$$\text{Power Output} = \frac{\text{(Peak-to-Peak Current)}}{2\sqrt{2}} \times \frac{\text{(Peak-to-Peak Volts)}}{2\sqrt{2}}$$

Now the peak-to-peak current of the equivalent composite valve is 2PS, and the peak-to-peak voltage is 2SR (see Fig. 5) so that

$$\text{Power Output} = \frac{2PS}{2\sqrt{2}} \times \frac{2SR}{2\sqrt{2}}$$

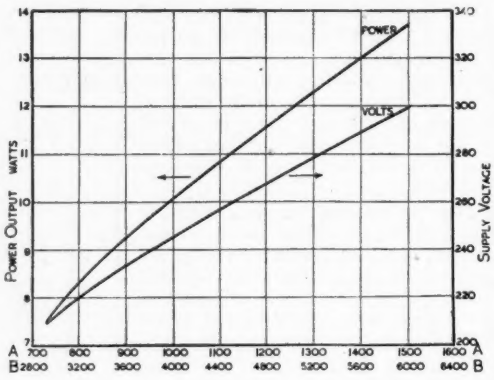

Fig. 6. Performance of two idealised Type A triodes in push pull.
Scale A. **Reciprocal of slope of path of operation of equivalent composite valve (ohms).**
Scale B. **Effective anode to anode load in ohms.**

$$= \text{area of } \Delta \text{ PSR which is given by Equation (10)}$$

$$= \frac{2km_1^2}{(m_1 + m)^2}$$

where k = maximum safe anode dissipation of the individual valves.

m_1 = slope of OA and O′A′ (anode characteristics for zero grid bias).

m = slope of the operating path of the equivalent composite valve.

From the above expression it follows that, as in the case of the single ended triode, the power will increase with increase of load resistance providing no limitations are placed on the supply voltage.

Anode Power Supply and Efficiency

The power supply to the triodes in push-pull and the anode efficiency require a knowledge of the *average* anode current of the individual valves.

This average current is not the same as the quiescent current I_Q of the single-ended valve due to the coupling between the separate halves of the primary winding of the output transformer. The value, however, can be determined either by the usual graphical methods or from the expression given by B. J. Thompson as:— Average Anode Current/valve =

$$I_Q + \frac{I_{amax} + I_{amin} - 2I_Q}{4} \quad \ldots\ldots (24)$$

from which follow the power supply and efficiency.

The average anode current and the path of operation of the individual valve depend on the value of grid bias voltage, and it is possible with the operating path of the composite valve tangential to the curves of maximum anode dissipation that the instantaneous anode dissipation will exceed the maximum over a portion of the operation cycle, although the average anode dissipation can be made less than this by suitable choice of grid bias voltage. In the interests of efficiency the grid bias voltage can be increased until the limiting condition of Class A amplification is reached.

Comparison Between Single Triode and Push-Pull Triodes

For the same load resistance, the power obtainable from two triodes in push pull is very nearly twice that from an identical single triode, and while the anode efficiencies in both cases is about the same, the corresponding supply voltage for the triodes in push pull is considerably lower.

If, however, the supply voltage is maintained at the same value, the effective anode to anode load for the triodes in push pull is about 50 per cent. greater than the corresponding load resistance for the single triode and the power output is about 2½ times that of the single triode.

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A Modification to Ray Theory Allowing for Ground Contours

By H. PAUL WILLIAMS,* Ph.D., A.M.I.E.E.

This article considers the effect of ground contours on idealised ray theory as applied to ultra-short wave propagation. An empirical formula is derived which gives excellent agreement with the published field strength contours of the Alexandra Palace television station. The wavelength used in these experiments was 7.2 metres and the radiated power 3 kilowatts. It should be realised that the deductions are only applicable to wavelengths of this order and that their validity in, say, microwave propagation is open to question.

UNDER certain conditions (which are frequently obeyed in ultra-short and microwave radio links) the calculation of the field strength at the receiving end of the link may be made by assuming ordinary optical theory and using Fresnel's reflection coefficients. The conditions which must be fulfilled for this assumption will not be discussed in the present article. Suffice it to say, in the case of Alexandra Palace, they are obeyed for any point of reception near the ground up to a radius of 20 miles. The conditions are met to a sufficient degree of accuracy for the use of ray theory as a first approximation for distances up to 30 miles, hence ordinary ray theory may justifiably be used for the published field strength curves of Alexandra Palace.

Unfortunately the ray theory makes no allowance for the fact that several reflections normally take place from the ground, while in addition a certain amount of diffraction will take place. The situation may be summarised in a typical case, as shown in Fig. 1. Fig. 1(a) gives the assumptions made with simple ray theory, while Fig. 1(b) gives an indication of the actual state of affairs. It is, therefore, of considerable interest to note the deviations of the actual field strength from the calculated values and whether this deviation is great enough to enable some form of correction factor to be applied.

Field Strength of Alexandra Palace

The polarisation of radiation from Alexandra Palace is vertical, so that the appropriate field strength formula is the one given below :—

$$E = \frac{7\sqrt{W}}{d^2}\left[\frac{2\epsilon'(h_T + h_R)}{\sqrt{\epsilon' - 1}} + j\frac{4\pi h_T h_R}{\lambda}\right]$$

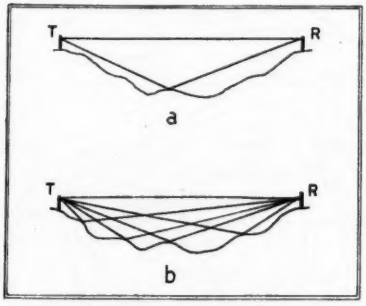

Fig. 1. Geometry of ray transmission.
a. Normal assumption of single reflected ray.
b. Illustration of multi-reflections.

where E = field strength in volts per metre.
W = radiated power in watts.
d = distance in metres
$h_{T,R}$ = height of transmitter or receiver in metres.
λ = wavelength in metres.
ϵ' = complex dielectric constant. $= \epsilon_r - j60\lambda g$.
ϵ_r = relative dielectric constant.
g = conductivity in mhos per metre.

The curves shown in Fig. 2 (p. 20) of relative field strength versus height of receiver are based on the above formula. Then the field strength for various distances can be readily determined by using the fact that E varies inversely with the square of the distance. It was found that the best fit with experimental results was given by a curve $\epsilon_r = 11$, $g = 0.01$. The experimental curves are stated to be field strength "on the ground"—we may conveniently assume that field strength is measured at a distance of $\frac{1}{2}$ wavelength above the ground. (It will be noticed that the variation of the field strength with height close to the surface of the ground is small.)

The above assumptions result in a field strength of 0.2 millivolts per metre at a distance of about 35 kilometres and give a fair approximation to the field strengths shown in the experimental curves. It will be realised that so far the calculation has only given a family of concentric circles which form the first possible approximation to the published curves. This family is shown in Fig.

Table used in determining "Ground Contour Law"

Place.	D in Kms.	h_1 in metres	h_2 in metres	Dip $= \frac{h_1 + h_2}{2}$	Field Strength Factor	Effective height h_R	Dip/3. in metres
Caterham ..	35	120	30	90	10	38	30
Kingswood ..	40	80	30	70	6.25	23	23
High Beech	13.5	0	80	80	7.2	27	27
Barnet ..	8	30	15	30	2.6	8	10
Chobham ..	40	0	80	80	7.2	27	27
Streatham ..	19	−30	60	45	1	0	15
Banstead Sutton ..	30.5	−30	60	45	3.6	13	15

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The London Television Station

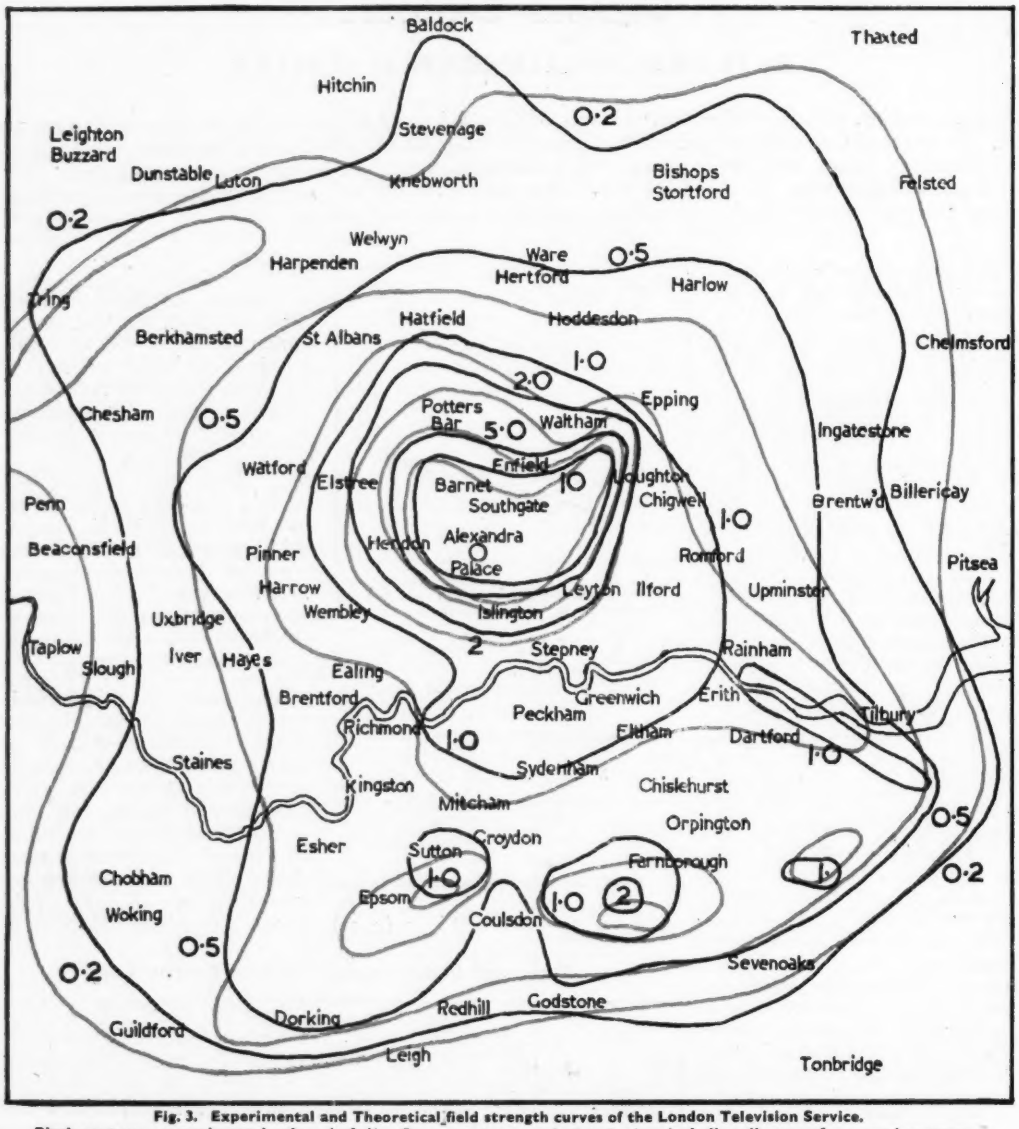

Fig. 3. Experimental and Theoretical field strength curves of the London Television Service.
Black contours—experimental values (ref. 1). Green contours—calculated values including allowance for ground contours.
Field strength figures in millivolts per metre.

4, while Fig. 3 shows the experimental curves with calculated curves superimposed.

The problem now becomes whether the theoretical curves can be improved upon by making some allowance for the actual variations in ground level. This problem is considered in the next section.

Empirical Law for Ground Contours

A study of the experimental curves will soon indicate that incorrect results will be obtained if the calculation is based in the normal manner on the relative heights of the transmitting and receiving antennae, together with the height of the mid-point. The problem is therefore more complicated and the need for a more elaborate formula is indicated. However, one has to be careful not to devise too complicated an empirical formula in order to account for these differences—the fact is that, by choosing a sufficient number of terms, it is always possible to create a formula which will fit the facts. Indeed, in

— Field Strength Curves

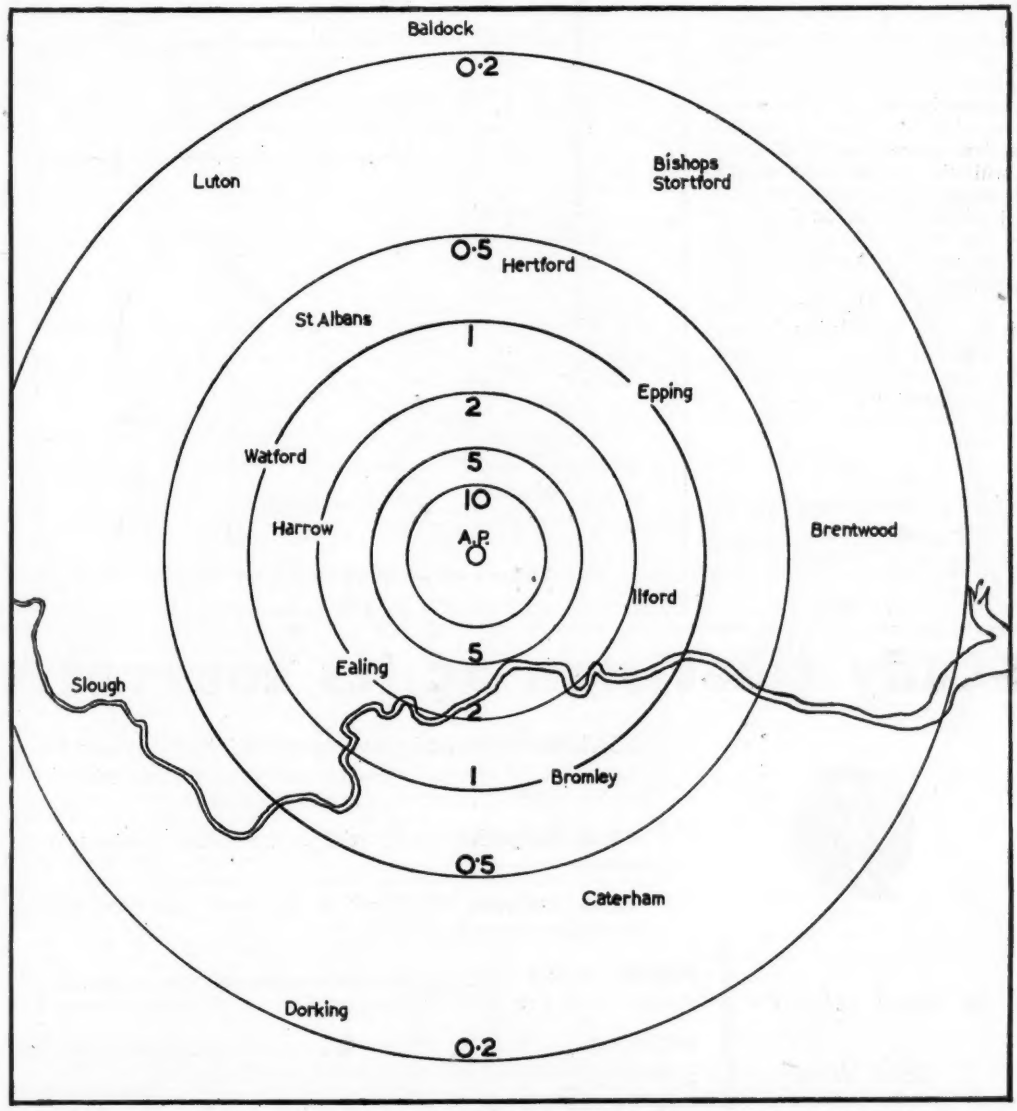

Fig. 4. Calculated field strength curves without regard to ground contours. The field strength contours are marked in millivolts per metre.

the first efforts in this direction, quite an involved formula was devised to account for contour irregularities.

Subsequently it was discovered that the following simple rule gave very satisfactory results: We find the height of the line joining the transmitting and receiving antennae above the mid-point of the intervening ground (Fig. 5) and then assume that the receiving antenna height, h_R, is equal to $\frac{1}{3}$ of this height (this height is referred to as the "dip" in the table given below).

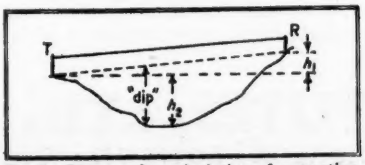

Fig. 5. Diagram for calculation of correcting factor.

The rule was based on an analysis of the places tabulated on p. 17.

It will be seen from the above table that (with the sole exception of

Streatham) the agreement between the last two columns is very satisfactory. The column marked "Field Strength Factor" gives the number of times the field strength is greater than that calculated by Equation (1). Applying this rule to the field strength contours of Fig. 4 gives the result shown in Fig. 5. It is at once apparent that the new theoretical values show greatly increased agreement with the experimental values. Thus a simple empirical law has been devised which, in conjunction with normal ray theory, gives greatly improved correlation with experimental field strength curves on a wavelength of seven metres. This law, therefore, is of value in assisting the prediction of field strengths at such wavelengths, whenever the intervening territory lies below the level of the ground at the points of transmission and reception.

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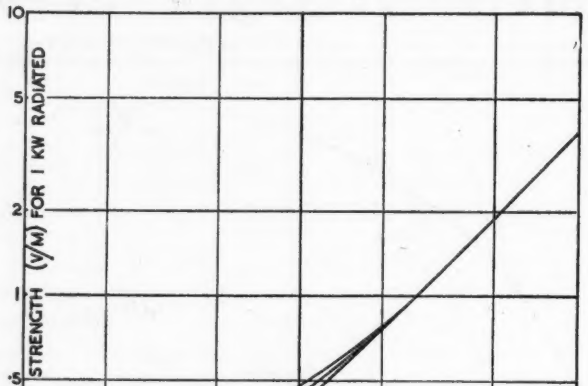

Fig. 2. Basic curves for calculation of field strengths (h_T=100 m. h_R=3.5 m)

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The Interstage Auto-Transformer at Television Frequencies

By PAUL FELDMANN, B.Sc.*

THE usefulness of the auto-transformer at television frequencies consists mainly in its structural simplicity and the ease with which it can be tuned. Its main applications are in the isolator stage of receivers, when it is preceded and followed by conventional transformer coupled stages; or when incorporated in a receiver employing staggered circuits. Most often the auto-transformer takes the form of a single coil of several turns of wire and is connected as shown in Fig. 1. The circuit of Fig. 2 is a diagrammatic representation of the relevant parts of Fig. 1. As will be seen from the condition of resonance, the mutual inductance m does not explicitly appear in the Equation (2), except in as far as it is inherent in the parameters L_1 and L_2 in the form

$$L_1 = l_1 + m; \text{ and } L_2 = l_2 + m \quad (1)$$

The coupling condenser, directly connected to the tap of the coil as shown in Fig. 1, is assumed infinite in the analysis, since all the gain or band-width variations which might be obtained by varying its magnitude can also be obtained by varying the tapping ratio of the coil. Although it may appear that by choosing a small condenser the input damping appearing across L_2 could be made less effective, the loss of output potential due to the introduction of this condenser more than nullifies the hypothetical advantage. A lengthy analytical investigation is required to sustain this intuitive argument, and will not be elaborated here. However, the experimental results obtained by varying the value of the coupling-condenser C are shown in the table below, in evidence of the correctness of the theory.

The frequency-separation between the natural resonance frequency ω and the actual resonance-frequency of the damped circuit is of the order of 0.1 per cent. of either, so that no appreciable error arises through the use of the natural instead of the actual condition of resonance. Considering now this condition, *i.e.*, when the reactive component of the impedance between anode and ground becomes infinite, we get

$$\omega^2[C_a(L_1 + L_2) + C_2L_2] = 1 + \theta \quad \ldots (2)$$

where

$$\theta = (\omega^2 C_1 L_2).(\omega^2 C_a L_1) \quad \ldots\ldots (3)$$

* P.R.T. Laboratories, Ltd.

SYMBOLS

R_p = plate resistance of amplifier valve.
R_i = parallel input resistance of stage following the amplifier valve.
R_f = equivalent parallel resistance of whole coil at the resonant frequency.
C_p = output capacity of the amplifier valve.
C_a = effective output capacity; consisting of C_d and stray capacities across the whole inductance.
L_1 = effective inductance of anode-tap portion of the coil, consisting of the inductance, l_1 of that portion of the coil, and of the mutual inductance m reflected into it by virtue of its coupling to the lower part of the coil.
L_2 = effective inductance of tap-earth portion of coil, consisting of the inductance l_2 of that portion of the coil in series with the mutual inductance m reflected into it by virtue of its coupling to the upper part of the coil.
C_i = hot input capacity of the stage following the amplifier.
g = the effective slope of the amplifier valve, defined by the relation $g = gm\ Rp/Rp + Rf$, where gm is the static slope of the valve.
ω = resonant frequency in radians per second.
Rf = effective anode-load of amplifier on resonance, external to the valve.
R_a = effective anode resistance at resonance, defined by the relation $1/Ra = 1/Rp + 1/Rl$.

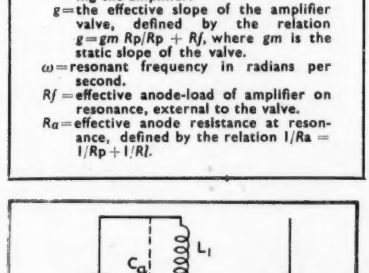


Fig. 1 (above). Fig. 2 (below).

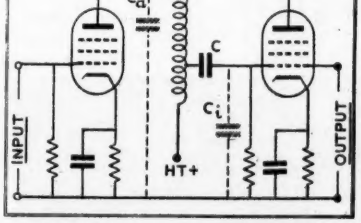


Table: Effect of varying C in Fig. 1.

C	Band width at $1/\sqrt{2}$ gain	Gain
5pF	.41Mc	10
10pF	.50Mc	23
20pF	.69Mc	35
60pF	.90Mc	37
100pF	1.00Mc	37
250pF	1.19Mc	37
350pF	1.22Mc	37

For any given valve (or valves) the variation in magnitude of θ, at a given frequency, depends merely on the variation of the product $L_1.L_2$. Although θ can easily be evaluated, this is in general not necessary for every position of the tapping, since, except when the tapping is made very near to either end of the coil—cases of little interest—the product $L_1.L_2$ is sensibly constant. As is seen from (2) the dimensions of θ are zero, and in the case of all the pentodes now (including midgets) used for television purposes its magnitude at 45 Mc/s. does not exceed .32.

Having imposed upon the circuit the condition of resonance, the peak gain will be a function of the resistive terms only.

The only resistances of the circuit are R_a and R_1.

Now in order to find the resistance R'_1, which when placed across the whole coil, would be equivalent to the resistance R_1 appearing across the inductance L_2, we have to transform the impedances as illustrated in Fig. 3.

If the given impedance is equal to the transformed impedance, we get:

$$\frac{j\omega R_1'(L_1 + L_2)}{R_1' + j\omega(L_1 + L_2)} = \frac{j\omega R_1 L_2}{R_1 + j\omega L_2} + j\omega L_1 \quad \ldots\ldots (4)$$

which yields, on evaluation,

$$R'_1 = \frac{R_1(L_1 + L_2)^2}{L_2^2} - \frac{j\omega L_1(L_1 + L_2)}{L_2} \quad \ldots\ldots (5)$$

At television frequencies the modulus of the imaginary term is of order of 1-2 per cent. of the term including the ratio of the square of the effective inductances, and will be neglected. Hence we get

$$R_1' = \frac{R_1(L_1 + L_2)^2}{L_2^2} \quad \ldots\ldots (6)$$

The total effective resistance of the circuit at resonance is that consisting of the parallel combination of R_a with R'_1 and is equal to R_f, where

$$R_f = \frac{R_1' \cdot R_a}{R_1' + R_a} \quad \ldots\ldots (7)$$

or, using Eqn. (6)

$$R_f = \frac{R_1 R_a(L_1 + L_2)^2}{R_1(L_1 + L_2)^2 + R_a L_2^2} \quad \ldots (8)$$

Now the total gain, as it would be measured at the anode by a very high-impedance instrument would be G_a, where

$$G_a = g.R_t \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

However, the gain at resonance, appearing at the input of the stage following the amplifier, G, will be less than G_a, namely:

$$G = G_a.L_2/L_1 + L_2 = g.R_t.L_2/L_1 + L_2 \quad (10)$$

Using the last equation together with (8), we get

$$G = \frac{g.R_1.R_a.L_2(L_1 + L_2)}{R_1.(L_1 + L_2)^2 + R_a.L_2^2} \quad \ldots\ldots\ldots \quad (11)$$

Provided that L_1 and L_2 are known the above relation enables us to evaluate the stage-gain for any position of the tapping point on the coil. When, however, it is necessary to investigate the variation of gain at resonance as function of only one variable parameter, say, L_2, then, since we do not know the corresponding value of L_1, which would keep the frequency at its desired value, difficulties arise. To overcome them, we evaluate L_1 from Equ. (3) and substitute it in Equation (11); getting

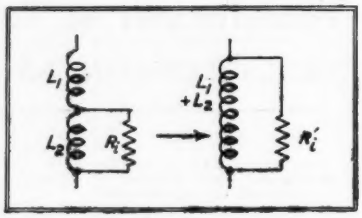


Fig. 3.

$$L_1 = \left[\frac{1 + \theta}{\omega^2} - L_2.(C_a + C_1)\right] \Big/ C_a$$

and $\quad \ldots\ldots \quad (12)$

$$G = \frac{g.R_1.R_a\left[\dfrac{1 + \theta}{\omega^2 L_2} - C_1.\right]}{R_1\left[\dfrac{1 + \theta}{\omega^2 L_2} - C_1.\right] + C_a^2.R_a} \quad \ldots\ldots \quad (13)$$

The last equation enables us to calculate the stage-gain without the explicit use of L_1.

To study the variations of G with respect to L_2, *i.e.*, the position of the tapping point, we evaluate dG/dL_2 from (13) and equate this to zero, when we obtain for maximum possible transformer gain

$$\left(\frac{R_a}{R_1}\right)^{\frac{1}{2}} = \left[\frac{1 + \theta}{\omega^2 L_2.C_1} - 1\right]\frac{C_1}{C_a} \quad \ldots\ldots \quad (14)$$

To obtain the band-width of the response curve (which, incidentally is for all purposes similar in shape to the single-peak response curve of an ordinary paralled tuned circuit) we use the well known relation

$$\Delta\omega/\omega = 1/Q = \omega(L_1 + L_2)/R_t \quad \ldots \quad (15)$$

or, using (10) and (15) we get for the band area ($\Delta\omega G$) the relation:

$$\Delta\omega.G = \omega^2 g.L_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (16)$$

In the experiment in which l_1=.817 μH, l_2=.337 μH, m=.113 μH, R_1 = 2,350 ohms; g = 5.7 mA/V, L_1=.930 μH, L_2=.450 μH, R_p=50,000 ohms, R_1 = 180,000 ohms; C = 300 pF; ω = 43.6 Mc/s.; R_t = 20,000 Ω; the following results were obtained, in good agreement with theory.

	G	$\Delta\omega.G/2\pi$	$\Delta\omega./2\pi$
Experimental ...	37.0	$45.1.10^6$	$1.22.10^6$
From theory ...	36.7	$44.4.10^6$	$1.20.10^6$

A Universal Oscillograph — *Continued from page 10.*

sumes its charged position, ready for the next positive impulse fed to the first grid of V_3. It is up to the operator to adjust the speed so that during the time T only one full sweep may occur which is easy enough for the picture is necessarily a standing one.

How to produce this pulse is beyond the scope of the instrument because it all depends on what kind of phenomenon is to be observed, how it is to be tripped, whether it is a long or a short transient, etc., etc. For slow transients a simple keying arrangement with a 10 V battery will be quite satisfactory. For fast transients, however, it will be found that it is impossible to produce a reliable pulse mechanically due to constant bouncing, etc., and some electronic Kipp relay will have to be used. But, as said before, it would be almost impossible to include a circuit covering all varieties of transients, so that the only feasible provision in the instrument appeared to be the inclusion of a switch S_3 which selects between the two operations: continuous sweep, and single stroke sweep. Besides, an 8-pin plug was provided at the back of the instrument to permit the external use of the oscillograph H.T. powerpack for such auxiliary circuits To show the possibilities of the single stroke arrangement the photograph of

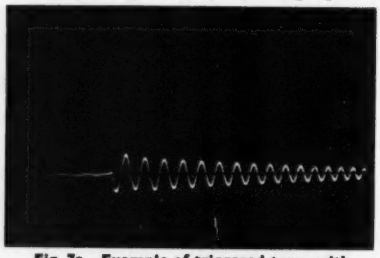


Fig. 7a. Example of triggered trace with single stroke time base.

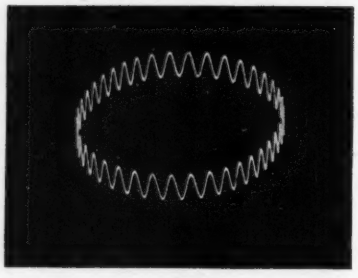


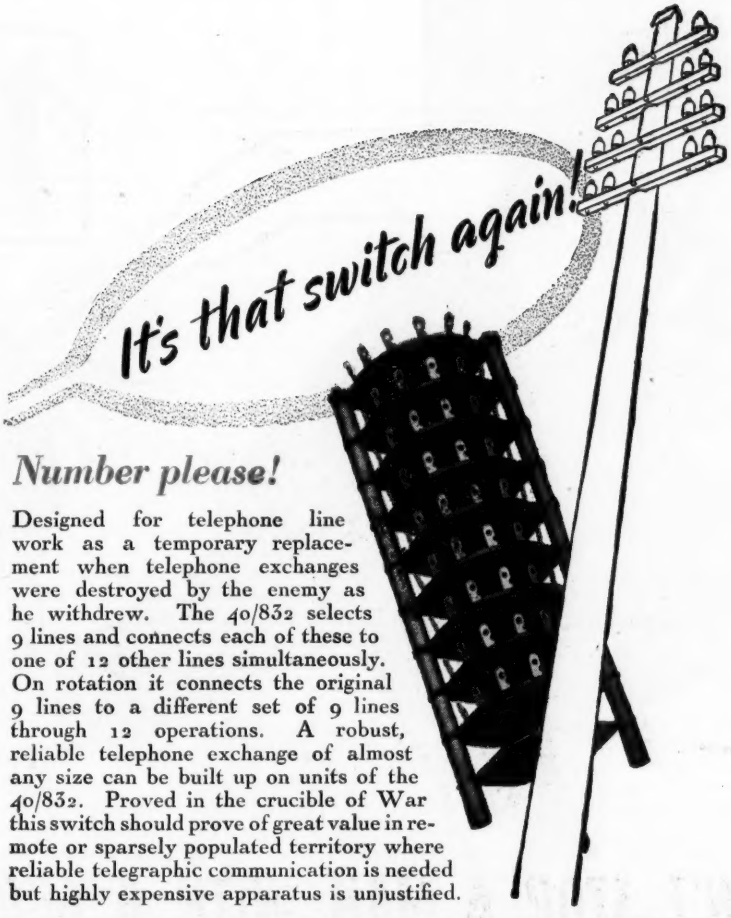
Fig. 7b. Waveform displayed on elliptic time base.

Fig. 7a is reproduced. It shows a 5 megacycle damped wave train excited 50 times a second by an auxiliary circuit which also produced the 3 microsecond pulse actuating the single stroke time base. The stationary spot which is bound to occur at the left end of the trace caused by : 19997 microsecond long pause of the beam between the actual sweeps was suppressed by feeding the positive 3 microsecond pulse to the modulator grid of the cathode ray tube via C_{80}, so that the beam is only switched on for the duration of the sweep.

2.3 The Elliptic Time Base

For many purposes it is very convenient to use an elliptic instead of a saw tooth time base. Due to the absence of a flyback the whole cycle can be observed, a fact which has applications in pulse work, for instance, for television purposes. Also it is of convenient use for determining the order of harmonics in the harmonic analysis in audio work since a stationary picture can be obtained similar to Fig. 7b which permits easy counting of the waves

(To be continued)



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LORIVAL PLASTICS

UNITED EBONITE AND LORIVAL LIMITED, LITTLE LEVER, NEAR BOLTON, LANCS

Perfect v. Pleasing Reproduction

By J. MOIR, M.I.E.E. *

IT is common experience that the majority of the ordinary members of the public prefer to operate the radio receiver with the tone control in the position that minimises the " top " response. Discussion of this practice has probably occupied more time at " Sound Quality " lectures than any other single problem, and it may be said with perfect safety that the generally accepted explanation is that the public does not like the amplitude distortion introduced by the average radio receiver, preferring the lesser evil of " top cut." There can be no doubt that the effects of amplitude distortion, surface noise, sideband splash, etc., are minimised by " top cut," but a feeling that other reasons, possibly more fundamental, may lie behind such a universal practice led the writer to give further consideration to other possibilities.

To put the problem into its proper perspective we must have a clear understanding of our target! Is it the engineers' job to produce " pleasing reproduction " or *a perfect reproduction* of the studio performance? Purists will probably consider the implied suggestion that " pleasing reproduction " and " a perfect reproduction " are not the same thing, as rank heresy, but the writer cannot see any *a priori* reason for agreeing with this view. To do so would imply that the present range of musical instruments had reached perfection. Irrespective of the engineers decision on this point, the public, knowing little of the fundamentals involved, will choose to have the " most pleasing reproduction " whenever the engineer places the choice in their hands. The public, having given the answer to these problems in no uncertain voice, and as it is certainly not the answer an engineer would expect, we must make an honest endeavour to decide whether the particular choice has been made because of defects in the engineering or because of some more fundamental factor.

It cannot be disputed that amplitude distortion leads to a tendency to restrict the frequency range if that facility is available. This is perfectly reasonable, for a reproducer with a range extending to 10,000 cycles per second will reproduce up to the 20th harmonic of a 500 cycle note, while a reproducer having a range up to 3,000 cycles per second can only deal with the 6th harmonic of the same note. The chance of dissonance between two notes increases with increase in their harmonic content, owing to beats between harmonics. Use of the " top cut " control will therefore decrease the unpleasant effects of amplitude distortion, and it is to be expected that its use would be more effective when a combination of instruments is being reproduced because of small differences in the tuning of individual instruments producing beats between the higher harmonics.

In considering the whole problem it is necessary first of all to decide what amount of distortion is just recognisable. This problem has been the target of several investigations, and to indicate the order of the problem, the results obtained by Massa (in 1933)[1] are presented in Table 1. The experimental method was obvious and straight forward. A high quality reproducer system was used, arrangements being made to introduce a known amount of second or third harmonic distortion without alteration of other factors. In one series of tests, listeners were asked to judge the onset of distortion without being given the opportunity of comparing the distorted with an undistorted reproduction, while in the second series of tests, a direct comparison between distorted and undistorted reproduction was possible. The tests were repeated with reproducer frequency ranges of 14 kc/s., 8 kc/s. and 5 kc/s., and it will be observed from Table 1 that under the stringent test of direct comparison, the minimum discernible distortion varied between 3 per cent. for the 14 kc/s. wide system and 12 per cent. for the 5 kc/s. wide system. More extensive tests by Braunmühl and Weber (in 1937)[2] gave similar results, giving support to the generally accepted figure of 5 per cent. as the desirable upper limit for a high quality reproducer system.

Bearing this figure in mind we will adroitly (but with considerable misgiving) side step the question as to the relative importance of harmonic distortion and intermodulation distortion and consider the results of a more recent series of tests in which a reproducer of the highest calibre was used to determine the frequency range which would produce the *most pleasing reproduction.*

These tests[3] were much more extensive than those briefly discussed above in that separate comparisons were made on a wide variety of programme material, with a series of frequency range restriction filters giving the frequency characteristics shown in Fig. 1. These were chosen as being representative of a system of the highest calibre (3 db. down at 30 and 9,000 cycles), an average quality radio receiver (3 db. down at 160 and 3,500 cycles) and a receiver midway between these limits (3 db. down at 70 and 6,500 cycles).

Particular care was taken to eliminate the possible effects of such secondary factors as order of presentation, appearance of the loudspeaker, effect of signal lights, etc. High quality disk recordings have the advantage of consistency and repeatability and as a separate test indicated that the results were not appreciably modified by their use, disks were employed for the majority of the tests.

The audience chosen (about 500 people) was representative of a wide variety of possible tastes, the majority being normal members of the public. It might be expected that a specialised group of listeners, such as those owning frequency modulation receivers, would display a more elevated taste than the ordinary man-in-the-street; who might reasonably be expected to

TABLE I

AUDIBLE DISTORTION LIMITS

Cut-off Frequency	Comparison with		Undistorted		No comparison	
	% 2nd		% 3rd		% 2nd	% 3rd
14 Kc	5		3		10	5
8 Kc	5		5		10	7
5	12		10		17	10

* Research Laboratory, B.T.-H. Co., Rugby.

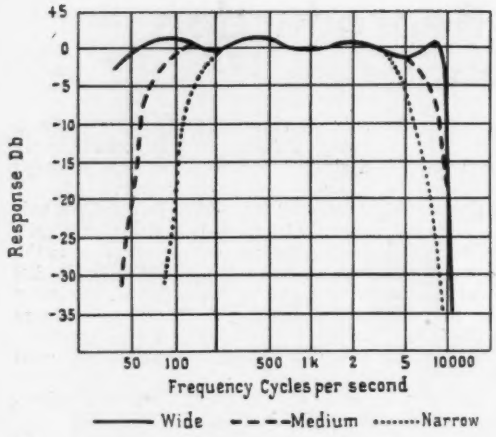


Fig. 1 (left). Frequency characteristics used for quality judgment.

Fig. 2 (below). Frequency characteristic of Loudspeakers used in Washington tests.

be accustomed to something worse than the narrow range reproducer. In America high quality reproduction is one of the main advantages claimed for frequency modulation technique and steps are taken to make certain that the receivers meet this claim. The even more specialised group of listeners composed of professional musicians accustomed to hearing music, etc. "in the natural," might be expected to exhibit an even more refined taste. Separate tests were therefore taken on a group of people owning frequency modulation receivers and on a group of musicians.

A wide variety of programme material was made available, separate tests being taken on each type, resulting in the array of results summarised in Table 2.

To say the least, the results are surprising. When wide range is compared directly with the medium range, the later scores in eight out of the eleven comparisons, wide range failing to make a decisive score at any point. On the tests where wide range might be expected to score (musicians and frequency modulation listeners) it is in fact most decisively rejected, the musicians being particularly single minded in their rejection.

On comparing wide range with narrow range the result is found to be almost as emphatic, narrow range scoring in nine out of the eleven comparisons.

The results of the comparison between medium range and narrow range does a little to restore the engineer's self confidence, in that medium range scores in seven out of the eleven tests with one match drawn and a large percentage of the audience having no preference.

The results cannot fail to surprise the quality enthusiast, particularly as it should be noted that the usual accompaniment to "high fidelity," surface noise, monkey chatter, whistles, etc., were absent.

To the best of the writer's knowledge no comparable tests have been taken in England, but some doubts about the results discussed led to a review of some of the data presented in a paper[4] describing the equipment used by the Bell Laboratories in demonstrating the wide range stereophonic reproducer system in Washington and Philadelphia in 1933. In this instance a quality comparison was not the target, the aim being to give a demonstration of a three channel stereophonic transmission system. As part of this system the whole of the lines amplifiers, modulators, etc.,

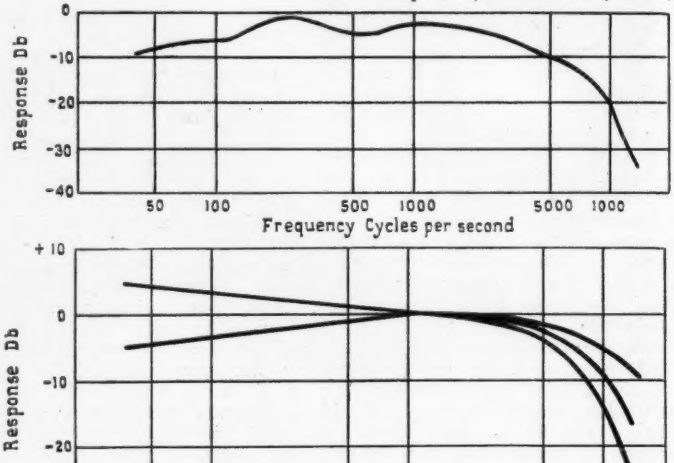


Fig. 3 (above). Frequency characteristics used in Washington Tests.

Fig. 4 (below). Overall Frequency characteristic (adjusted for best aural results).

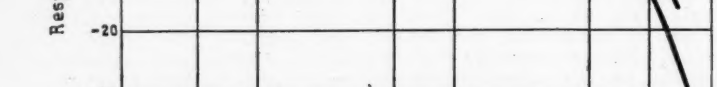


TABLE II
FREQUENCY RANGE PREFERENCES

Range	Classical Music	Male Speech	Piano Music	Light Music	Female Speech	Mixed Speech	Musicians Classical Music	Musicians Male Speech	Freq. Mod. Listeners Classical Music	Freq. Mod. Listeners Male Speech	Live talent Light Music
Wide	12	21	28	39	30	15	7	25	16	14	11
Medium	67	55	24	22	26	64	83	48	61	63	70
No preference	21	24	48	39	44	21	10	27	23	23	19
Wide	15	24	24	33	34	23	5	48	28	36	26
Narrow	58	48	30	34	29	45	73	40	59	48	40
No preference	27	28	46	33	37	32	22	12	13	16	34
Medium	19	52	25	33	46	34	20	02	31	55	21
Narrow	38	25	20	26	33	34	28	10	28	31	26
No preference	43	23	55	41	21	32	52	28	41	14	53

Wide Range is 3 db down at 30 cycles and 9000 cycles.
Medium Range is 3 db down at 70 cycles and 6500 cycles.
Narrow Range is 3 db down at 160 cycles and 3500 cycles.
Figures are per cent. of votes cast.

were equalised to give a frequency characteristic flat to within 1 db. over the whole range of 40 cycles to 20,000 cycles, with total measured distortions of about 1 per cent. and a signal/noise ratio of greater than 70 db.

The frequency characteristic of the speaker system is given in Fig. 2 and it is noted that measured in a large room (*i.e.*, the condition of use) there is a relative loss of 17 db. at 10 kc/s. Part of this may be offset by a rise of about 7 db. in the same part of the frequency range of the microphone used, but it is particularly interesting to note that in the tone control networks provided, arrangements are made to increase the L.F. response by as much as 4 db. at 40 cycles per second, but there is no provision for any similar increase in "top" response. Instead the networks are arranged to insert an H.F. cut up to approximately 15 db. at 10 kc/s. (Fig. 3). Presumably this H.F. loss was only provided after careful testing had shown it to be advantageous.

In another field there is further evidence of the advantages of operating a sound reproducer with a drooping frequency characteristic at the upper end. Fig. 4 indicates the overall frequency characteristic recommended by the American Academy of Motion Picture Arts and Science[5, 5a] after careful comparison tests in several theatres. Our own experience confirms this choice.

In the space available for an article of this nature, it is not possible to quote further evidence in favour, so that we will conclude this section with the assumption that after every effort has been made to reduce distortion, noise, etc., to a minimum, the human ear still prefers the frequency range to be restricted at the upper end of the scale.

A critical review of the evidence quoted in favour of this viewpoint will immediately raise some points on which the evidence is not so conclusive as is really desirable. In the test results quoted (Table 2) there were no distortion or frequency characteristics taken on the specific set of speakers used for the test, though there were stated to be units of the highest quality and a group of expert listeners agreed on the excellence of their performance. These points were, however, taken care of in the Bell laboratory series of tests, a figure in the region of 1 per cent. being quoted. One might raise the objection that even this figure is too high and that it is thus incorrect to describe this system as distortionless, the restriction in frequency range being required to deal with this residual distortion. However, after giving consideration to the data quoted in the first section, it would appear that this objection is without weight. In fact after making a close study of the human hearing mechanism the writer feels surprised that 5 per cent. distortion is detectable, as an addition to the really serious distortion occurring within the ear. In this respect it is worth noting that the tone quality (harmonic content) of almost every instrument varies enormously with loudness in normal playing and yet little impression of unpleasant distortion is given.

If our electro-acoustic equipment is really distortionless (*i.e.*, if 1 or 2 per cent. is of little consequence) one is immediately led to consider whether the same preference would be shown for restricted top response if electro-acoustic equipment was not involved as a link between instrument and listener.

To the best of the writer's knowledge this point has not been checked, but an interest in the mechanics of musical instruments led to a review of some of the information that is relevant.

Violins of the old Italian masters (circa 1700), such as Amati, Guarnerius, Stradivarius, etc., have a reputation amongst musicians that is unrivalled by that of any later product, and while a lot of this may be pure "sales talk" it is apparent that a few really top rank artistes can distinguish without hesitation a violin of this period from the very best copies by later craftsmen. Now it would be ridiculous to assume that the frequency response of a violin was the only factor that determined tone quality, but there is no doubt that it is a very important factor. This question of violin tone quality has been the subject of a very thorough (but as yet uncompleted) investigation by a group at Harvard University[6]. Many lines of thought have been followed, but as our present interest is in "frequency characteristics" we will confine discussion to that factor alone.

Sound radiation from an instrument of the violin type takes place mainly from the body, the bowed strings serving only as a method of excitation. Thus, if the strings are driven

TABLE III

FREQUENCY RESPONSE OF VARIOUS VIOLINS

Frequency Range	196 cycles to 349 cycles	349 cycles to 784 cycles	784 cycles to 1568 cycles	1568 cycles to 3136 cycles	3136 cycles to 4186 cycles	4186 cycles to 6272 cycles
Average Stradivarius	14.1	23.7	25.7	25.9	23.6	10.9
Guarnieri's Heifetz choice ..	15.3	27.2	25.7	28.7	21.4	10.85
Bad Violin No. 1 ..	12.12	16.1	25.7	20.4	19.7	15.35
Bad Violin No. 2 ..	3.2	25.1	25.7	51.9	20.9	20.1

Figures are Intensities in arbitrary units.

at different frequencies by any convenient means the sound radiation from the body can be measured in just the manner used in taking loudspeaker response curves. This procedure has been followed for a group of the most famous models by Stradivarius, certain models by other famous masters, a selection of copies by current master craftsmen, and other models where the manufacturer had obviously kept both eyes firmly fixed on a price target. In reaching decisions on tone quality, the Harvard group had the invaluable guidance and co-operation of such eminent artistes as Jascha Heifetz, Sacha Jacobson, etc.

Table 3 presents the result in tabular form for easy comparison, but a few words about the method of expressing the results is necessary before proceeding to the Table. The frequency range covered has been divided into frequency bands of roughly an octave and the figure given is the response (intensity in arbitary units) averaged between the frequency limits quoted at the top of the column, and in order to make comparison easier the outputs have all been equalised in band 3, appropriate correction being applied to all other readings. The frequency characteristic is thus indicated directly without any further allowance having to be made for sound output differences between instruments.

Line 1 is the average performance for a group of seven of the most famous instruments by Stradivarius, instruments about which the musical world is uniformly enthusiastic.

Line 2 is the characteristic of a Guarnerius model, chosen by Heifetz for his own use.

Lines 3 and 4 are similar data on low priced models, which the critics agreed as being thoroughly bad.

The results are illuminating, good violins are characterised by a response which falls off fairly rapidly above 4,000 cycles per second, while the bad models have a response which is well maintained up to, and beyond, 6,300 cycles. At a low frequency end the good models are again characterised by a well maintained output, while the response of the bad models fall away in the same manner as a poor amplifier.

In a good instrument the lower tone will thus be rich and full with prominent partials (or harmonics), while the upper notes will tend towards pure tones, or at least only the lower partials will be well represented. This is particularly interesting as it is exactly the result that is obtained from a good piano.

If we assume the correctness of this thesis, it should be possible to trace similar tendencies in the trend of development of other orchestral instruments, although as musical development is an art and not a science it is to be expected that the time scale will be measured in hundreds rather than in tens of years. Nevertheless, the results can be just as positive as those obtained by any scientific process.

Tracing the development of any orchestral instrument is a rather difficult proposition, as instruments may, and do, become obsolete for reasons other than tone quality. Restricted range, difficulty of fingering or blowing, size or even mere fashion may end the popularity of an instrument.

In spite of this, the modern oboe is believed to be a fair example of instrument development. Originating from the 12th century Shawm, a conically bored wooden instrument with a double, reed the instrument is described by Geiringer as "having all the power and astringent vigour demanded by the age," or as having "a shrill bleating tone." By another authority[2] as "an excruciating noise much more penetrating than a trumpet." By the 17th century it had become advantageous to modify the reed and mouthpiece, making (to quote Geiringer[1] again) "It is softer and more delicate" a certain indication that the top response had been modified by the removal of some of the upper partials.

By the 20th century the instrument had become the modern oboe with a characteristic, common to most of the other orchestral instruments, the lower and middle ranges having strong upper partials, while the higher notes tend toward pure tones.

The advantage (or otherwise) of reducing the upper end of the frequency scale can be checked by the reader in a very simple manner when listening to an actual orchestral performance, preferably when listening to the performance of a brass band in the open air. The acoustic output of instruments like the trombone and trumpet is largely concentrated along the axis of the horn, the concentration becoming more marked at high frequencies. Thus the frequency characteristic is "flat" on the axis, while the high frequency output falls relative to the 500 cycle components as the listener moves off the axis, *i.e.*, "Top cut," can be put in without electrical equipment being involved. If this experiment is tried indoors the listener should be fairly close to the instrument in order to minimise the effect of reflections.

The theme will not be pressed further, but instead an attempt to draw some conclusion will be made.

It appears that in a high quality reproducer system with total distortions 10-15 db. below the level at which separate tests indicate distortion as "just noticeable," public preference for a restricted frequency range exists. This optimum range is approximately 3 db. down at 70 cycles and 6,500 cycles, but is somewhat dependent on programme material.

A similar preference appears to exist when electrical reproduction is not involved, except that an even more restricted range appears to be preferred, though absolute data on this point is not as complete as is desirable.

It does appear that the presence of distortion is not the only reason for the general desire to "cut top."

In providing a tone control the engineer is making it possible for the great mass of the general public to

express an opinion on a subject that has previously been the prerogative of musical circles. It is suggested that this opinion serves to confirm the general trend of the tone quality of orchestral instruments, though further investigation is required.

Insofar as the public tend to go further than musical instrument designers have gone in removing the upper partials it would appear that some organised investigation of public preference is necssary as a guide to the designers of musical instruments.

Assuming the correctness of the present thesis it may be well asked, "What is the communication engineer going to do about it?" It is suggested that the present practice of transmitting with a flat or slightly rising characteristic and providing each listener with a tone control is the correct procedure. This gives a measure of pre-emphasis and de-emphasis, which, while not going as far as American practice goes (wrongly, in the writer's opinion), does provide a useful improvement in signal/noise ratio.

As to the technically minded listener, it is suggested that he forgets his preconceived ideas on where the tone controls should be set and adjusts them to give the most pleasing reproduction. To save the conscience it would be a good idea to keep a log of the settings found most pleasing with different types of programmes, and after about a year try and analyse the results with a view to ascertaining the preferred frequency characteristic.

In presenting this information on such a widely debated subject, the writer has attempted to avoid inserting any personal bias either for or against the subject matter. The results present a disconcerting discontinuity in our previous line of thought and it would appear imperative to obtain some further evidence of the mass reaction to frequency range restriction. The individual opinion of an engineer would appear to be less important than that of an ordinary member of the public lacking all knowledge of the prior art.

References

[1] Massa, *Proc. I.R.E.*, May, 1933.
[2] Braunmuhl and Weber, *Akusiche Zeits* v.2, p. 135, 1937.
[3] Chinn and Eisenberg, *Proc. I.R.E.*, Sept., 1945.
[4] Fletcher, *Bell System Technical Journal*, April, 1934.
[5] Durst and Shortt, *J.S.M.P.E.*, p. 169, v. 32, 1939.
[6] Mason and Moir, *J.I.E.E.*, Sept., 1941.
[7] Saunders, *J.A.S.A.*, Jan., 1946.
[8] Geiringer, "History of Musical Instruments."
[9] Stanford and Forsyth, "History of Music."

CORRESPONDENCE

Mass and Energy — A Misconception

IN last month's issue a letter to *Science* from Dr. C. R. Eddy was reproduced in which he corrected the conception that matter and energy were inter-convertible. This letter has been followed by other comments in *Science* (Oct. 25), of which a selection is appended below:

Apparently Eddy, in his article, is using mass in both senses without distinguishing how the term is being used. For example, he says the equation $E = mc^2$ "does not state that a mass, m, can be converted into an energy, E . . . "; and later he says that "it was assumed that M is essentially at rest," where "M is the mass of the fissionable nucleus plus the neutron added to trigger it off." In these cases it is evident that mass is being used to mean matter. Near the end of the article he says that "the mass of a photon is $h\gamma/c^2$," where evidently mass is used to mean inertia. Thus, would not the article be clearer if the term mass were used in only one sense, *e.g.*, mass being defined as inertia? . . .

According to our present theory, when a fission occurs, there are the same kind and number of elementary particles of matter after fission as before, but the sum of the inertias of the remaining particles is less than the sum of the inertias of the initial particles. The difference in these inertias is called the mass (inertia), m, that has disappeared; and the energy that appears in the form of kinetic energy and gamma radiation equals mc^2. This may be thought of as a transfer of energy from one form to another form, or as the mass (inertia), m, being converted into energy. The quantity of matter in this case remains unchanged. . . .

. . . Eddy's conclusion that the law of conservation of mass (inertia) still holds is correct. But it is also correct that matter and energy are interconvertible, as evidenced in the cases where the positron and electron unite and disappear, the photon or photons appearing, and where the positron and electron appear at the disappearance of a photon. At least, these are the present interpretations of the experimental evidence.

VOLA P. BARTON.
Goucher College, Baltimore.

The conclusion of Eddy that "the law of conservation of mass still holds" is purely a question of definition. It may readily be seen that $m = m_o + \Delta m$, where Δm is a kinetic increment equal to the kinetic energy of a particle divided by c^2. In atomic disintegrations, rest mass Σm_o is not conserved in any case, and relativistic mass $\Sigma(m_o + \Delta m)$ is not conserved when radiation is emitted. In the case of radiation, the quantity $h\gamma/c^2$ has the dimension $[M]$. In accord with disintegration phenomena, $h\gamma/c^2$ is called the *equivalent mass* of a photon. It is desirable to maintain a distinction between mass of a particle and equivalent mass of a photon in order to preserve appropriate distinction between matter and radiation.

AUSTIN J. O'LEARY.
City College of New York.

Complex Waveforms

DEAR SIR,—In connexion with the article by Dr. Hilary Moss on "Complex Waveforms" in the June and August issues, the following points concerning the envelope method of analysis may be of interest to your readers:

(a) In case (a), p. 182, the envelopes may be regarded as generated by the H.F. ripple as the phase of this component relative to the L.F. component is varied continuously, *i.e.*, the lines are the envelopes, in the mathematical sense, of the family of curves obtained by varying the relative phase ϕ in the form
$$f(\phi) = A\sin.\theta + B\sin(k\theta + \phi)$$

(b) In case (b), the envelopes are similarly generated by varying the relative phase ϕ in the form $f(t) = A\sin(\omega t + \phi) + B\sin(\omega t + \delta\omega t + \phi)$ where the notation used in the article has been slightly modified. The reason for the modification is that a bulge of the beat occurs at $t = o$ in the form given here, irrespective of the value of ϕ.

These two facts form the basis of the envelope method. The theory of the method is being described in a thesis and may be published later.

Yours faithfully,
R. G. MANLEY

DEAR SIR,—I thank Mr. Manley for his contribution which serves to unify the bases of the Envelope Method of wave analysis, and which he so ably expounds in his book.

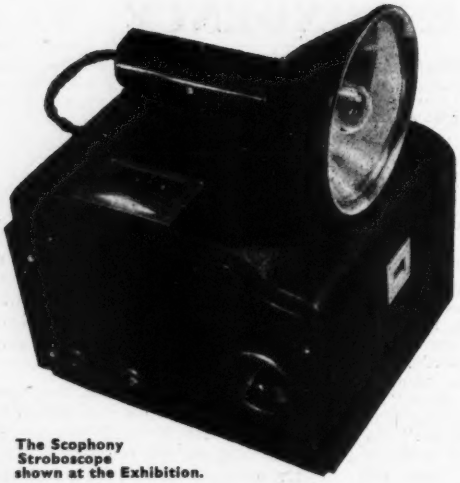
His remarks under paragraph (b) are the mathematical statement of my comment regarding Fig. 7 in paragraph 3, column 3, page 243 of the August issue. It is there pointed out that

"Change of the relative phase of the two component waves merely moves the position of the resultant wave within the envelope, but has no effect on the envelope itself."

Yours faithfully,
HILARY MOSS

The Glasgow Technical Exhibition

The first post-war Scottish Technical Exhibition was held at the Kelvin Hall, Glasgow, from Nov. 15th.-27th. 1946. A brief review of some of the items shown is given below.



The Scophony Stroboscope shown at the Exhibition.

Accessories—Miscellaneous

Reading Lamp.

A portable folding reading lamp to clip on to a bench, chair, or bed without damage to the material. Can be adjusted to any position and folds up neatly to enable it to be carried in pocket or bag.

Forson Design & Engineering Co., Ltd., West Street, Portslade-by-Sea, Sussex.

Domestic Distribution Panels.

A house-service unit made to EDA Specification 1627, with kitchen control unit for control and distribution of electrical supply in consumer's premises. The unit comprises switches, pilot lamps and fuses, with spares, clearly labelled and mounted in a protective steel cabinet for fixing in wall.

A Reyrolle & Co., Ltd., Hebburn.

Anti-vibration Mountings.

Bonded rubber-metal mountings and resilient coupling units for motors and engines. A wide range of standard couplings is available from fractional horse-power to heavy drives, which will also allow for misalignment of shafts.

Rubber Bonders, Ltd., Dunstable, Beds.

Hotplate Control Unit.

The "Simmerstat" hot-plate control unit provides continuously variable control of heat in electric hotplates for domestic cookers and similar equipment.

Sunvic Controls, Ltd., Kean Street, London, W.C.2.

H.F. Equipment

"Redifon" radio heaters, type RH.7 and RH.23 are H.F. heating generators of 2 kW and 250 W. respectively, suitable for pre-heating of moulding powders, non-metallic parts, etc. The larger unit will heat glue joints and is particularly suitable for industrial applications.

Exhibited by Atkins, Robertson & Whiteford, 100 Torrisdale Street, Glasgow.

Instruments—Measuring

Gauges.

Dial gauges with English and metric readings, to measure up to 4-in. dia. Gauges for measuring bores for roundness and parallelism.

Catmur Machine Tool Corpn., Ltd., 247 Vauxhall Bridge Road, London, S.W.1.

Standard slide gauge, capacity 10 ft., with vernier readings to 0.001 in. for use as a master Vernier Height gauges of "V" section with quick and sensitive adjustment. Improved vernier calliper gauges.

James Chesterman & Co., Ltd., Bow Works, Sheffield, 11.

Plug and ring gauges, taper and spline gauges, vertical comparators, sine bars and test bars.

Mollart Engineering Co., Ltd., Kingston By-Pass, Surbiton, Surrey.

Jigs, fixtures, and gauges of all types.

Vernier Gauge & Tool Co., Longford, Coventry.

Measuring Instruments—Industrial.

Moisture-in-grain and moisture-in-timber meters.

Plating thickness meter.

Chronoscope, measuring time intervals of 1m.sec. upwards.

Impulse counter, with single pointer and dial divided into 25 units. Automatic reset.

*p*H meter, mains operated, of high input resistance.

Marconi Instruments, Ltd., St. Albans, Herts.

Meters.

Miniature and switchboard meters from 2 in. to 8 in. diameter in moving iron and moving coil types, substandard meters, and portable industrial measuring instruments manufactured by Measuring Instruments (Pullin), Ltd.

Exhibited by Land, Speight & Co., Ltd., 73 Robertson Street, Glasgow.

Instruments—Optical

Vertical enlarger for ½-plate, automatically focusing between ⅜ reduction to 6 x enlargements. The carrier will accommodate a whole-plate negative and will enlarge from any ½-plate portion of this negative.

Miniature projector for 35 mm. film or 2 in. by 2 in. slides, with interchangeable lenses of 4 in. and 6 in. focal length.

Aldis Bros., Ltd., Hall Green, Birmingham 28.

The "Stewartry" Universal Enlarger, built on a unit principle to enable it to be used for other work, such as copying or projection. The negative stage can be rotated, and the unit is fitted with interchangeable masks. Further accessories to be available are copying lights, film back for roll film, and high and low power lamp housings.

G.B. Montgomery Mnfg. Co., 95 Bath Street, Glasgow, C2.

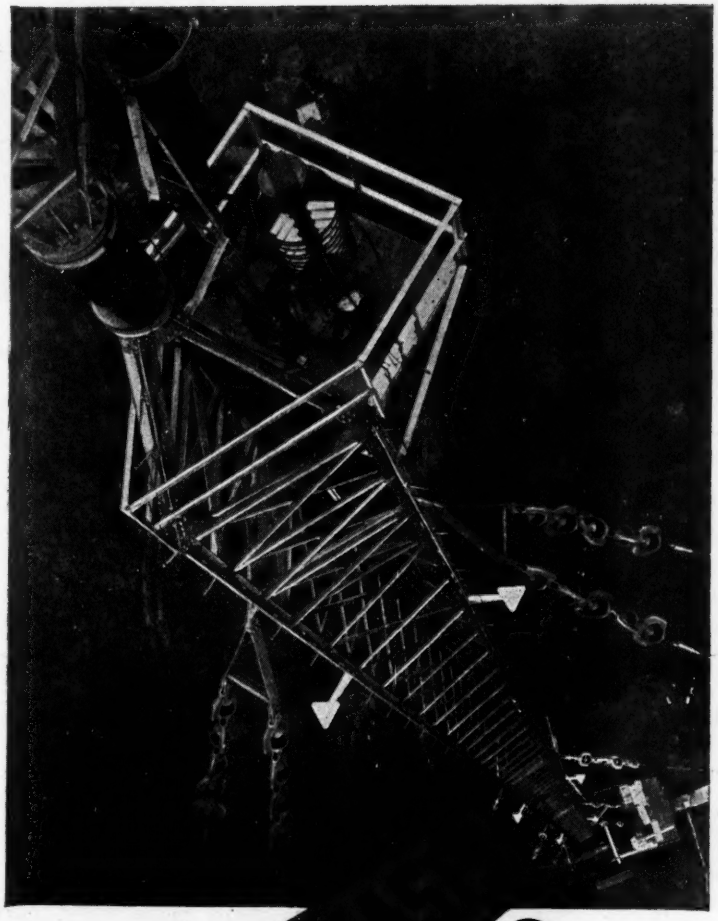
Leica accessories, lens caps, filter holders and filters, etc.

G.B. Montgomery Mnfg. Co., 95 Bath Street, Glasgow, C2.

Drawing Office Equipment.

Reflex camera equipment.

Central Drawing Office Co., Buchanan Street, Glasgow.



B.I. Callender's

Pivoted upon oil-filled insulators at base, and the 400-ft. level, supported by 21 insulated guys, this 500-ft. galvanised steel mast is fully insulated from earth. It was designed and erected by B.I. Callender's for the B.B.C.'s Brookman's Park transmitter and is typical of the work we are doing on radio masts and towers in all parts of the world.

BRITISH INSULATED CALLENDER'S CABLES LIMITED

NORFOLK HOUSE, NORFOLK STREET, LONDON W.C.2

MARCONI INSTRUMENTS LTD

Specialists in
Measurement for Communications
can now offer their

OUTPUT POWER METER

TYPE TF 340

FOR IMMEDIATE DELIVERY

The instrument indicates directly the power delivered by an audio-frequency system into a variable external load provided by the Meter itself. Its technical efficiency is in the highest Marconi tradition. Full technical information available on request.

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ST. ALBANS, HERTS. Phone: ST. ALBANS 4323/6

Northern Office: 30 ALBION STREET, HULL. Phone: Hull 16144

Western Office: 10 PORTVIEW ROAD, AVONMOUTH. Phone: Avonmouth 438 Southern Office: 109 EATON SQUARE, LONDON, S.W.1. Phone: Sloane 8615

ERG'S HAVE THE URGE TO GO ABROAD

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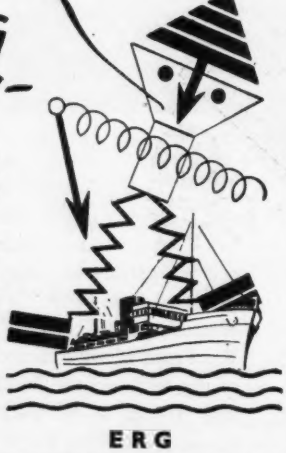

ERG Resistors have an exceptional electrical specification and performance, with mechanical strength.

High Grade Vitreous Enamels used on our Tropical Resistors give long life, and definitely assist in the trouble-free manufacture and performance of Radio Receivers, Television and Test Equipment.

Processed up to the highest Service Standards at a competitive price.

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Provided with clear, open scales 3½" long. Flush pattern moulded cases. Well damped; suitable for D.C. & A.C. up to 100 cycles. Readings independent of wide variations in wave form. Movement of spring-controlled, repulsion type with high torque/weight ratio. Ammeters self-contained to 50 Amps; power consumption does not exceed 1VA. Voltmeters self-contained to 500 Volts; power consumption 7.5VA.

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Dept. E, Great West Road, Brentford, Middlesex. Telephone: Ealing 0011

Drawing Office Equipment—*continued.*

The "Copycat." A photographic copier for use in a general office, employing neither dark room nor camera. It can be operated by unskilled labour and will reproduce any type of document in photographic facsimile. The standard unit consists of a reproduction unit, developing unit, and drier.

Miles Aircraft, Ltd., 335 Putney Bridge Road, London, S.W.15.

Plating and Metal Finishing

Metal spraying by "Metallisation" is applicable to practically any form of base, the metal coating being applied from a spray pistol to which it is fed in the form of wire. Metals which can be sprayed by this process include steels, stainless steel, copper, brass, nickel, etc. Complete spraying equipments are available.

Metallisation, Ltd., Barclay's Bank Chambers, Dudley, Worcs.

Rustproofing of ferrous metals by the deposition of zinc and cadmium. Uses of copper, nickel, chromium, tin, silver, gold, rhodium, speculum as decorative and protective finishes. Nickel and chromium for reclaiming worn or undermachined parts. Aluminium anodically treated to prevent corrosion. Aluminium anodically treated and dyed for decorative finishes. Uses of various stoved enamel finishes. Chemically oxydised and bronze finishes.

Electro-Platers, Ltd., 31/47 Townsend Street, Glasgow, C.4.

Radio Receivers

Scottish-made radio receivers, including a 5-valve super-het home model, concert model, and export model.

Allander Industries, Ltd., Milngavie, Glasgow.

The "Torrisdale" radiogram—an all-electric transportable radiogramophone of novel design.

Atkins, Robertson & Whiteford, 100 Torrisdale Street, Glasgow, S.2.

Coastal radio marine equipment: 100 W radio-telephone installation, with visual alignment indicator.

Exhibited by Land, Speight & Co., 73 Robertson Street, Glasgow, C.2.

Screws, Nuts, and Washers

Phillips patent recessed-head screws, self-tapping screws, and wood screws in aluminium, brass and mild steel.

"Aerotight" self-locking nuts in one piece, requiring only a spanner to tighten or loosen.

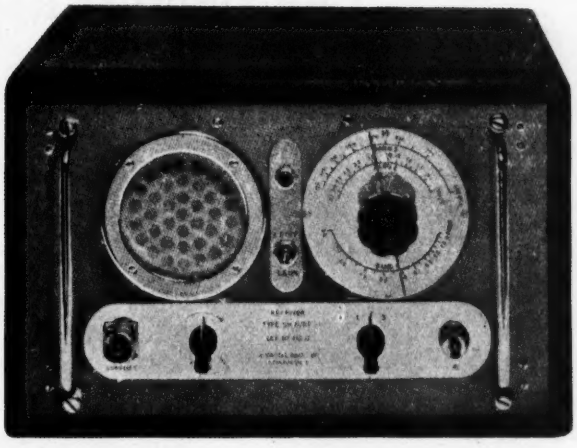
Guest Keen & Nettlefold, Ltd., Heath Street, Birmingham, 18.

"Philidas" self-locking nut in one piece—vibration-proof and locking either screwed to a face or unsupported. Sizes from 6 B.A. upwards, in brass, steel or aluminium alloy.

Philidas, Ltd., 1-31 Maclise Road, London, W.14.

Locking washers with overlapping teeth, internal or external, from 6 B.A. upwards, from 3s. 11d. per 1,000 plus 20 per cent. Countersunk washers are also available.

Fan Disc, Ltd., 111 Northwood Street, Birmingham, 3.



Receiver unit of coastal marine equipment. —Land Speight & Co.

Small Motors

Protected, ventilated motors from $\frac{1}{8}$ H.P. to $\frac{1}{2}$ H.P. with resilient cradle mounting. Sleeve or ball bearings, single phase or three-phase 200-240 V 50 c/s. and 360-440 V three-phase.

Inquiries for future production are invited.

Hoover, Ltd., Perivale, Greenford, Middx.

Fractional H.P. A.C. induction motors, and torque motor (see *Electronic Engineering* for 1946).

Scophony, Ltd., 36 Victoria Street, London, S.W.1.

Tools—Small

Non-electric magnetic chucks, independent of electrical supply problems for grinding, turning and bench use.

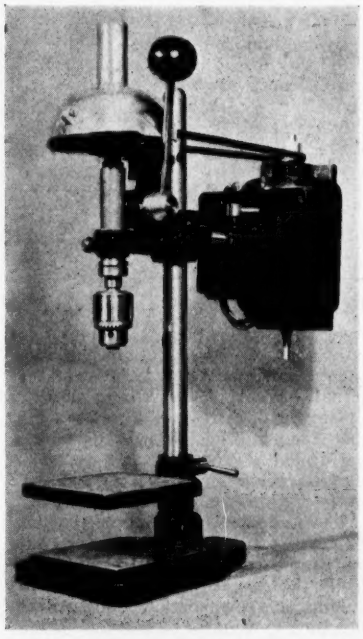
Twist drills, reamers, milling cutters: a complete range of high speed cutting tools which is fully illustrated and described in the firm's new catalogue.

The "Arbeluxe" $\frac{1}{4}$ in. Engineers Bench Drill. This machine is designed for hard and continuous use and the spindle runs in phosphor bronze and steel bushes, with provision for lubrication. Rack and pinion motion, with spring return to operating handle. Precision key type chuck $\frac{1}{4}$ in. capacity.

Available with single or 3-speed head. Price £8 7s. 0d. If fitted with Universal motor, pulley and belt, £12 12s. 0d. complete.

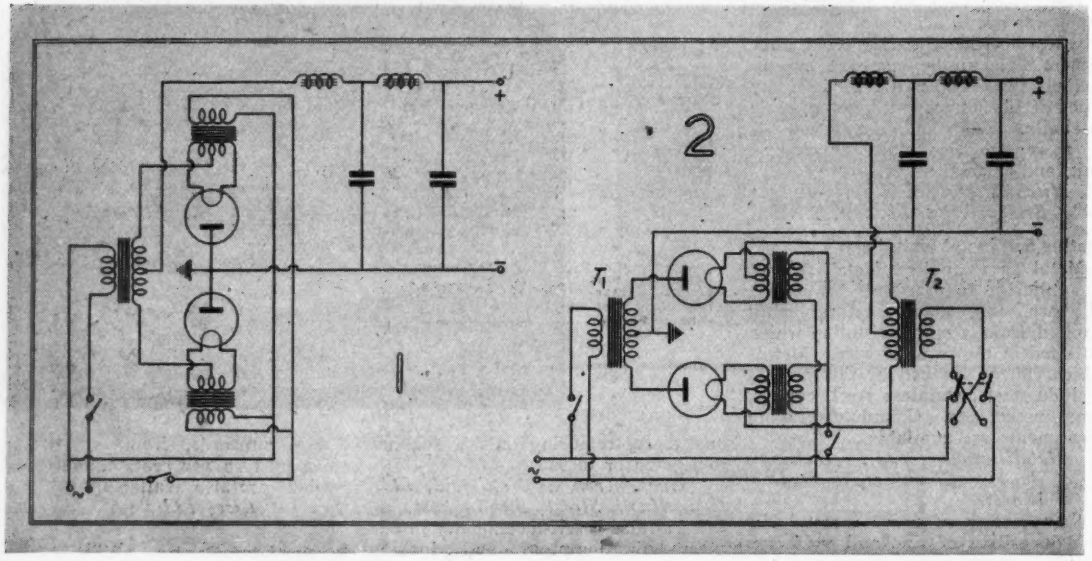
B. Arthur Hems, Ltd., 80 York Street, Glasgow, C.2.

(*Concluded overleaf*)



"Arbelux" Drill—see col. iii.

An Unusual Rectifier Circuit



IN an article under this title, Cmdr. E. E. Comstock describes in the November issue of "*QST*" an interesting form of circuit for obtaining four values of output voltage from a full-wave rectifier by the use of an additional transformer and changeover switch.

The circuit is a combination of the standard full-wave rectifier arrangement with an "inverted" circuit shown in Fig. 1. In this case separate heater windings are required for the two rectifiers, insulated to withstand the full voltage of the H.T. secondary winding.

By itself this circuit has several advantages over the more usual form. The top caps of the rectifiers are at earth potential and the ripple voltage in the output has been found to be less. The H.T. secondary leads of the transformer are by-passed to earth for radio frequencies by the inter-winding capacitance of the filament transformers, and the risk of H.F. leakage into the power supply is correspondingly reduced.

By combining this circuit with the standard form, the circuit of Fig. 2 is obtained. The additional transformer T_2 is connected to the mains through a D.P. changeover switch so as to reverse the phase of the A.C. applied to the rectifiers. Reversal of the phase will not, of course, affect the polarity of the D.C. output.

The total output voltage obtainable is then equal (neglecting smoothing drop) to the sum of the voltages obtained from T_1 and T_2, if they are in phase. On reversing the phase of T_2, the output voltage is then equal to the difference between the voltages.

If the primary of either transformer is open-circuited, the output voltage is then equal to the voltage of the other.

Additional advantages are that the secondary winding of the open-circuited transformer acts in this case as additional smoothing and that there is no undue loss of efficiency when operating with the transformers in phase opposition, as only the resulting voltage is rectified.

The filter constants are the same as for conventional power supplies of the same voltage and current ratings.

The Glasgow Technical Exhibition—*concluded*

The "Astoba" Universal Machine-tool is of Swiss manufacture and for which this firm are agents for the British Isles.

The outstanding features of the tool are the counter-balanced tilting bed which can be moved through an angle of 90°, and the perpendicular movement of the headstock unit.

The machine can be used as a 4½ in. centre screw-cutting lathe or as an 8¼ in. centre boring and facing lathe. It can also be used as a horizontal or vertical milling machine, a drilling machine with automatic feed and a capacity of ¾ in. in steel or a sensitive lever-feed drilling machine with a top speed of 4,000 r.p.m. By means of attachments many other operations, such as horizontal boring, internal, external or surface grinding, slotting, jig-sawing, die-filing, hack-sawing, tool and cutter grinding, etc., can be performed.

Precision Accessories, Ltd., 12 Ogle Street, London, W.1.

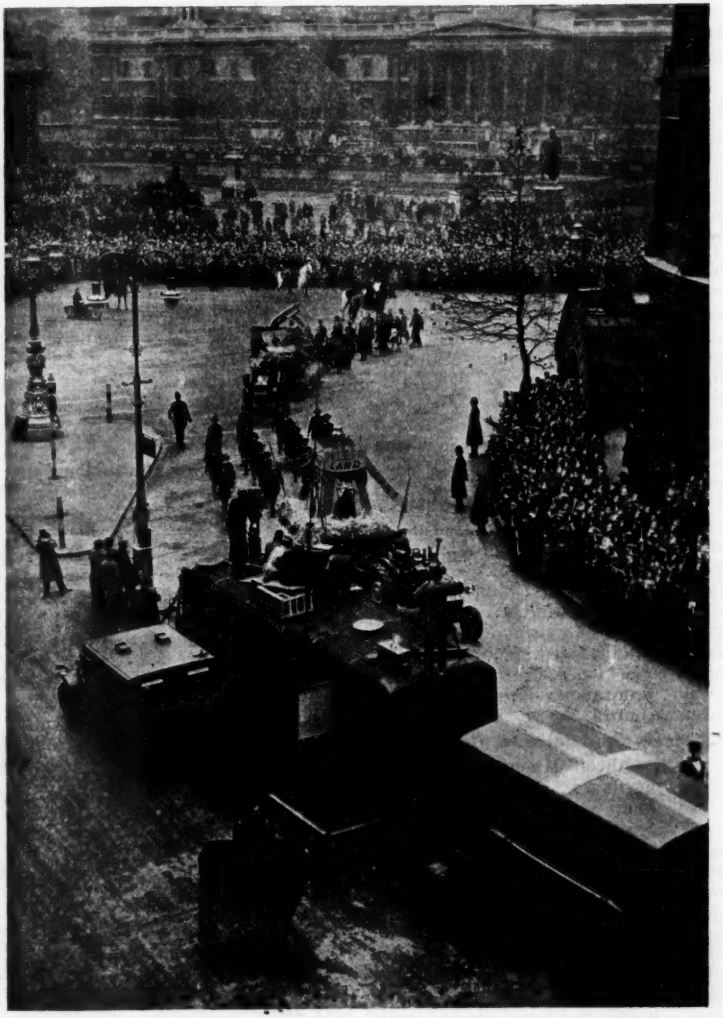
The Anderson "Vertimax" Production Lathe is a Scottish made machine and represents a striking departure from the usual practice as regards system of construction and general lay-out.

It is a vertical spindle chucking lathe with twin slides. The feed is hydraulic and the slides and hydraulic cylinders form units which can be swivelled through more than 120° from below the horizontal to beyond the vertical positions, making possible, apart from normal turning, the simultaneous machining of two internal tapers, two external tapers, or an internal and external taper.

It swings 15 in. diameter and its over-all dimensions are 36 in. by 60 in. by 54 in. high, and it requires the minimum of operating space.

John S. Young & Co., Ltd., 68 Gordon Street, Glasgow, C.1.

Television Commentary



The B.B.C. Television Service in action at the Lord Mayor's Show, November 9th, 1946. This excellent photograph shows the procession rounding Northumberland Avenue corner with the O.B. van in the foreground. The Emitron camera and film unit camera are on the roof.
—Photograph by courtesy of the B.B.C.

IN the past month, television has launched two new and promising serial programmes devised in its own idiom. "Kaleidoscope," on alternate Fridays, is a light magazine programme with some very bright features. "Pinwright's Progress," on the other Fridays, may turn out to be the "Itma" of television, for Ted Kavanagh has a hand in it.

Another milestone was the first full-length play televised from the stage. This was "George and Margaret," performed at the Intimate Theatre, Palmer's Green (December 2).

"Morning Departure" (December 1 and 3) was a fine handling of the tragic theme, once attempted by television before the war, of men entombed in a submarine. "The Beggar's Opera" (November 26 and 28) and "The Farjeon Revue" (November 30 and December 5) were two other high spots.

JEAN BARTLETT.

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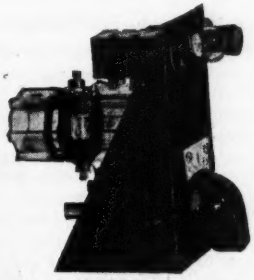
(SHORT WAVE) LTD
for Quality components

THE "Q-MAX" CHASSIS CUTTER

Does away with tiresome drilling and scraping. Holes cut easily and cleanly. Punch cuts through chassis, die prevents distortion, spanner turns bolt to cut holes.

Size of holes 1⅛ in. (octal) 10/6
" " 1½ in. " 12/6
(Post 9d. extra)
(Other sizes in production) *(Patent Applied for)*



THE "Q-MAX" ABSORPTION WAVEMETER AND PHONE MONITOR

An Absorption Wavemeter for checking frequency harmonics and parasitics in Oscillators, Doublers and Power Amplifiers.
All amateur bands covered by plug-in inductances. Incorporated in the Wavemeter is a WX6 Westector—automatically connected across the tuned circuit by inserting phone jack plug for monitoring phone transmissions. Size 3¾ in. by 2 in. by 2 in. Price ... 35/-
(Price includes one inductance. Extra inductances 3/9 each.)

Obtainable from your local Q-Max dealer or direct from :

BERRY'S (SHORTWAVE), LTD.
25, HIGH HOLBURN, LONDON, W.C.1
(Opposite Chancery Lane) *Tel. : HOL 6231*

NOTES FROM THE INDUSTRY

B.S.I. 1946 Yearbook

The Yearbook of the British Standards Institution, just published, gives a subject index and a synopsis of each of the 1,300 British Standards now current. These standards have been prepared by representative committees of 44 different industries. Also included are lists of members of the General Council of the Divisional Councils and of the Industry Committees of the Institution, as well as other useful information about its work. The Yearbook, price 2s. post free, can be obtained from the Publications Sales Department, British Standards Institution, 28 Victoria Street, London, S.W.1.

Radar Equipment in the "Queen Elizabeth"

The special mercantile radar navigation equipment in the "Queen Elizabeth" was installed by Cossor Radar, Ltd. The glass envelopes used in the cathode ray tubes were made of Chance Bros. glass, and the tubes themselves were supplied by Electronic Tubes, Ltd., for Cossor Radar, Ltd.

G.E.C. Audio Frequency Millivoltmeter

This new G.E.C. instrument is a useful addition to apparatus used in connexion with A.C. electrical power engineering. It provides a convenient and simple method of measuring small millivolt drops which occur in circuit breaker contacts, bus-bar connexions and heavy duty cable links, etc. The accuracy is approximately 3 per cent. full scale reading on all ranges with true sine wave output.

The circuit comprises a two-stage amplifier with negative feed back which stabilises the gain at 100. This is followed by a diode rectifier and a D.C. amplifier which has a degenerative action and so eliminates errors due to change in valve parameters. The amplifier is connected in a bridge circuit and the out of balance current indicates the voltage. The voltage ranges of the meter are 15, 50, 150 and 500 mV and 1.5, 5, 15, 50 and 150 V. Frequency range is 25 c/s. to 20 Kc/s. and the consumption is about 50 watts. It operates from 200-250 V, 40-100 c.p.s. supply.

The net weight of the millivoltmeter in its polished walnut case is 27¾ lb., and it measures 16 by 10 by 10½ in.

South-East London Technical Institute
Lewisham Way, S.E.4.

A Course of about 12 Lecture-Demonstrations on "Television Practice."
By: J. E. Jacob, B.Sc., A.M.I.E.E.; M. Morgan, M.Sc., A.Inst.P.; A. E. Sarson, B.Sc, A.Inst.P.; L. C. Jesty, B.Sc., M.I.E.E.; G. E. Graham, B.Sc., A.R.C.S, D.I.C., A.M.I.E.E.
Commencing January 16 at 7 p.m.
Applications for admission should be made to the Head of the Electrical Department as soon as possible. Fee £1 for the Course.

Carrier Frequency Wire Relay System

A carrier frequency wire relay system was formally inaugurated at Rugby on November 22 by Multi-Broadcast (Engineering), Ltd., 159 Station Road, Rugby, in conjunction with the British Thomson-Houston Co., Ltd. An experimental relay service has been set up in Rugby, and in due course Multi-Broadcast (Engineering), Ltd., will be prepared to install the carrier system for relay operators in other parts of the country. Each subscriber is supplied with equipment consisting of a cabinet loudspeaker and a 3-valve (plus rect.) receiving unit which requires an A.C. mains connexion. The controls are a 6-way programme selector and a volume control.

A New Sub-Miniature Thyratron

The Raytheon Manufacturing Co., of Newton, Mass., U.S.A., have introduced a new sub-miniature thyratron valve designated the RK61. This valve is designed for use as a self-quenching super-regenerative detector which will operate a high resistance relay in the anode circuit upon reception of a radio signal. The electrical characteristics are as follows:

Filament voltage (D.C.), 1.4 V. Filament current, 0.05 amps. Average tube voltage drop (at 1.5 mA), 30 V. Anode voltage, 45 V. Relay resistance, 5,000 to 10,000 ohms. Anode current (no signal), 1.0 to 1.5 mA. Anode current (with signal), 0.1 to 0.5 mA.

Head of New Mullard Laboratory.

Dr. C. F. Bareford, M.Sc., Ph.D., has been appointed manager and head of the new Mullard Electronics Research Laboratory at Cross Oak Lane, Salfords, near Horley, Surrey.

"G" Meter

Dawe Instruments, Ltd., have secured the manufacturing rights in this country of a "G" meter, made in America by Frederic D. Schottland, of New York. The instrument measures peak acceleration or deceleration values and is intended for tests on packages and articles subjected to shock or violent movement. It provides a measurement of the maximum instantaneous shock in terms of G (gravitational) units. The standard model is supplied with the following ten calibrated points: 2, 3, 5, 7, 10, 15, 20, 30, 50 and 70 G units. Alternative ranges can be supplied to special order. The meter consists of two parts: a pickup unit which normally replaces the article under test and an electronically operated indicator unit. Further details can be obtained from Dawe Instruments Ltd., Harlequin Avenue, Great West Road, Brentford, Middlesex.

Johnson Matthey House Journal

In November *The Bulletin,* house organ of Johnson Matthey & Co., Ltd., made its first appearance in its new form, and is now an attractively produced magazine containing 28 pages of informative articles and staff news. An interesting contribution in the November issue tells the story of the founding of Johnson & Sons' Smelting Works in the middle eighteenth century by John Johnson, "a jeweller and working goldsmith." It is proposed to issue the journal bi-monthly and in order to cover production costs a small charge of 3d. per copy will be made.

Scientific Instrument Manufacturers form Electronics Section.

Fourteen member firms of the Scientific Instrument Manufacturers' Association of Great Britain, Ltd., have formed an Electronics Section. The first chairman is Capt. A. G. D. West, director of Cinema-Television, Ltd., and the firms forming the section are:—

Baird and Tatlock (London) Ltd.
Baldwin Instrument Co., Ltd.
Cinema-Television, Ltd.
Adam Hilger, Ltd.
Henry Hughes and Son, Ltd.
Kelvin, Bottomley and Baird, Ltd.
Marconi Instruments, Ltd.
Mullard Wireless Service Co., Ltd.
Scophony, Ltd.
Short and Mason, Ltd.
Sperry Gyroscope Co., Ltd.
Sunvic Controls, Ltd.
Taylor Electrical Instruments, Ltd.
Taylor, Taylor and Hobson, Ltd.

One of the main objects of the Electronics Section will be to further and improve the manufacture of British electronic instruments and apparatus.

JANUARY MEETINGS

*NOTE.—In general, visitors are admitted to the meetings of scientific bodies on the invitation of a member, or on application in writing to the Organising Secretary at the address given. In certain cases (marked *) tickets may also be obtained on application to the Editorial offices of this Journal.*

Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Radio Section

Date: January 15. Time: 5.30 p.m.
Lecture: "Crystal Valves."
By: B. Leaney, M.A., D.Phil.; J. W. Ryde and T. H. Kinman, M.B.E.

Date: January 21. Time: 5.30 p.m.
Discussion: "Radio v. Line for Communications."
Opened by: A. H. Mumford, B.Sc., O.B.E.
The Secretary, I.E.E., Savoy Place, London, W.C.2.

Ordinary Meeting

Date: January 16. Time: 5.30 p.m.
Lecture: "Industrial Applications of Electronic Techniques."
By: H. A. Thomas, D.Sc.
The Secretary, I.E.E., Savoy Place, London, W.C.2.

London Students' Section

Date: January 8. Time: 7 p.m.
Lecture: "Radio Transmitting Valves."
By: A. Mason, B.Sc. (Eng.).
The Secretary, I.E.E., Savoy Place, London, W.C.2.

Cambridge and District Group

Date: January 7. Time: 6 p.m.
Held at: The Cambridgeshire Technical College.
Lecture: "A Standard of Frequency and its Applications."
By: C. F. Booth, M.I.E.E., and F. J. M. Laver, A.M.I.E.E.

Date: January 28. Time: 6 p.m.
Held at: The Cambridgeshire Technical College.
Lecture: "Ultra High Frequency Measurements."
By: C. W. Oatley, M.A., M.Sc., A.M.I.E.E.
Group Secretary: D. H. Hughes, c/o Pye Ltd., Radio Works, Cambridge.

The Institute of Physics

Electronics Group

Date: January 28. Time: 5.30 p.m.
Held at: Royal Society, Burlington House. Piccadilly, London, W.1.
Lecture: "Semi-Conductors."
By: Professor H. S. W. Massey.

Date: January 11. Time: 3.30 p.m.
Held at: The University College, Cardiff.
Lecture: "Contact Potentials."
By: Dr. F. A. Vick.
Note: This is a joint meeting with the South Wales Branch of the Institute of Physics.
Secretary: A. J. Maddock, B.S.I.R.A., "Sira," Southill Road, Chislehurst, Kent.

Industrial Radiology Group

Date: January 17. Time: 6.30 p.m.
Held at: The Electric Lamp Manufacturers' Association, 2, Savoy Hill, London, W.C.2.
Lecture: "Sonic Methods in Non-Destructive Testing."
By: R. Meakin, B.Sc., A.Inst.P.
Secretary: Dr. L. Mullins, Research Laboratories, Kodak Limited, Harrow, Middlesex.

Manchester and District Branch

Date: January 10. Time: 7 p.m.
Held at: New Physics Theatre, The University, Manchester.
Lecture: "Recent Developments of Calculating Machines in U.S.A."
By: Prof. D. R. Hartree, F.Inst.P., F.R.S.
Secretary: Dr. F. A. Vick, Physics Department, The University, Manchester 13.

Scottish Branch

Date: January 28. Time: 5.30 p.m.
Held at: The University, Edinburgh.
Lecture: "Photography of Atomic Tracks."
By: Prof. P. I. Dee, O.B.E., F.Inst.P.
Secretary: Mr. W. G. Marskell, Messrs. Babcock & Wilcox, Ltd., Renfrew.

The Television Society*

All meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Lecture:
"Frame Time Base Synchronisation."
By: A. W. Keen, M.I.R.E.

Brit. I.R.E.

Date: January 16. Time: 6 p.m.
Held at: The Savoy Hotel, W.C.1.
Lecture: "Pulse Technique."
By: M. M. Levy.
The Secretary: The British Institution of Radio Engineers, 9, Bedford Square, W.C.1.

The British Kinematograph Society*

Date: January 22. Time 7.15 p.m.
Held at: Gaumont-British Theatre, Film House, Wardour Street, W.1.
Lecture: "New Developments in Sound Technique and Equipment."
By: B. C. Sewell.
Note: This is a joint meeting with the Association of Cine-Technicians.

Society of Instrument Technology

Date: January 28. Time: 7 p.m.
Held at: Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, W.1.
W.1.
Lecture: "Some Applications of Electronics in the Iron and Steel Industry."
By: W. C. Fahie, M.Sc.
Secretary: L. B. Lambert, 55, Tudor Gardens, London, W.3.

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Telegrams: VACTITIC, SALFORD

ABSTRACTS OF ELECTRONIC LITERATURE

C. R. TUBES

The 5RP Multiband Tube : An Intensifier-Type C.R. Tube for High-Voltage Operation

(I. E. Lempert and R. Feldt)

At the medium voltages employed in conventional cathode-ray oscillographs (3 to 4 kilovolts), full advantage cannot be taken of high-frequency circuit performance either by photographic recording or visual observation, due to insufficient trace intensity. A new tube, the multiband tube, is described, which is essentially a high-voltage intensifier-type cathode-ray tube. Its cylindrical shape and the sub-division of the intensifier electrode into several bands (multi-band) reduce intensifier distortion to such an extent that the tube may be operated with good results at intensifier-to second-anode voltage ratios of 10:1. A low-capacitance deflection system, with leads brought through the tube neck, makes it particularly useful for high-frequency applications, and its nearly flat face simplifies the lens problem for photographic recording and projection. The tube can be used as a replacement for 5CP tubes on standard equipment with little change, except the addition of an external intensifier voltage supply. Typical operation is at Eb_2 1,500 volts, Eb_3 15,000 volts. Results are given and particular applications and modifications (projection, ultra-high-frequency tubes) are described.

—*Proc. I.R.E.*, July, 1946, p. 432.

CIRCUITS

The Cathode-Coupled Amplifier

(K. A. Pullen)

This paper gives a picture of the operation of the cathode-coupled amplifier and a study of methods of application in several new directions. Among these are the following: high-frequency amplifiers, multivibrators, audio oscillators, radio frequency oscillators, resonant-resistance determination, mixers, and other applications.

—*Proc. I.R.E.*, June, 1946, p. 402.W.

Class B Modulator Design

(R. W. Grant)

Deals with the design of the output filter generally used with high-power Class B modulators. The function of the filter is to divert the normal anode current of the modulated stage from the secondary winding of the transformer, but it can have an important effect on the response at the lowest audio frequencies. This aspect and that of cost are the determining factors. The effect on the design of the output transformer is also considered.

—*The Marconi Review*, Vol. 9, No. 2, p. 70.

MEASUREMENT

The Investigation of Electrostatic Fields by Means of a Valve Voltmeter

(R. Street)

The electrostatic field between two overlapping parallel planes has been investigated by means of a radioactive source and a valve electrometer. The equipotentials so obtained are in satisfactory agreement with the theoretical curves calculated from a Schwarz-Christoffel transformation. The experiment can be adapted as a laboratory exercise.

—*Jour. Sci. Inst.*, September, 1946, p. 203.

Ionosphere Measuring Equipment

(P. G. Sulzer)

The pulse-reflection technique of ionosphere investigation requires a transmitting and receiving system which sweeps in the region from 1 to 20 megacycles rapidly. Equipment described utilises a common oscillator to facilitate tracking, and broad-band response to obviate tuning.

—*Electronics*, July, 1946, p. 137.

Radio Investigation of the Ionosphere

(C. J. Bakker)

This article gives a survey of investigations made concerning the layers of ionized air (ionosphere) present in the atmosphere high above the earth, which are able to reflect radio waves back to the earth, thus making radio reception possible at a great distance beyond the horizon of the transmitter. Various phenomena in short-wave reception, such as fading and the skip distance, are due to the presence of the ionosphere. The density of ions and the so-called "effective" altitude of the ionosphere can be derived from measurements that have been taken. It has been found that particularly the density of ions, and also the reception of short waves, depends to a large extent upon the sun, namely, upon its height above the horizon and its eruptive activity. The main, but not the only cause of the ionization is in fact the irradiation of the atmosphere by sunlight, in particular by the part of the spectrum in the far ultra-violet. In the process of ionization this part of the sun's spectrum is absorbed and cannot, therefore, be observed on the earth. Interesting conclusions as to the intensity of the sun's radiation in the far ultra-violet can be drawn from data concerning the ionosphere obtained experimentally by means of reflected radio waves.

—*Philips Technical Review*, April, 1946, p. 111.

* Abstracts supplied by the courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester

INDUSTRY

Wire Recording

(D. W. Pugsley)

In discussing magnetic wire recording, the applications of light-weight portable equipment, which can operate under a wide variety of conditions, are reviewed. Advantages and disadvantages of this method over more conventional methods of recording are listed. Procedure involved in making a record is explained in a description of the mode of operation of the device, and it is stated that the method used most extensively is to superimpose a supersonic signal of frequency 30 to 50 kilo-cycles on the medium, simultaneously with the signal to be recorded. The quality of the reproduction is discussed together with possible applications of the method.

—*Elect. Engg.*, July, 1946, p. 136.*

Electronic Register Control for Multicolour Printing

(W. D. Cockrell)

The proper register for multicolour printing, that is, the printing of as many as five colours on top of one another to the required positional accuracy of a few thousandths of an inch, has been solved by the use of phototubes and associated electronic equipment. The electronic control system described includes error detecting equipment, indication of the position of the printing cylinder, mixing panel, and the correcting motor power panel. Thyratrons supply the current required to energize the correcting motor armature so as to give proper directional movement and speed for correct register. The mode of operation of a typical system is outlined together with aids for maintenance and repair.

—*Trans. A.I.E.E., August*, 1946, p. 617.*

Depreciation of Fluorescent Lamps Without Passage of Current

(H. C. Froelich)

Fluorescent lamps with thin and with partial coatings of phosphor on bulbs of ultraviolet transmitting glass were irradiated with Hg 2537 radiation. Comparison with similar lamps showed a decline in lumen output, of the same general character in all experiments except for different time factors. It is concluded that the process of lamp depreciation is fundamentally of photo-chemical nature, involving excited mercury, but not requiring either Hg ions or neutral atoms. It is assumed that superficial oxygen ions of the phosphor crystal react with Hg to form links of the type $SiO-O-Hg-Hg\ \ldots$, thus adding mercury to the crystal, with a resulting loss in phosphor brightness.

—*Jour. App. Phys.*, July, 1946, p. 573.*

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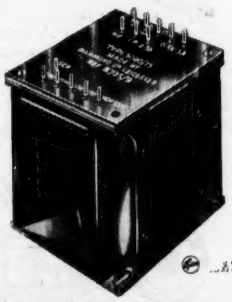

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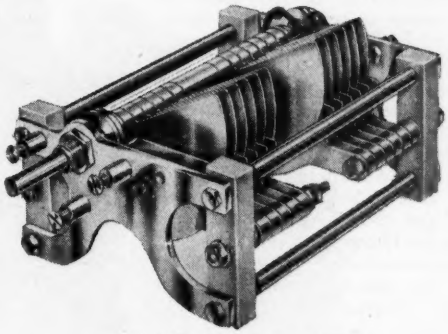

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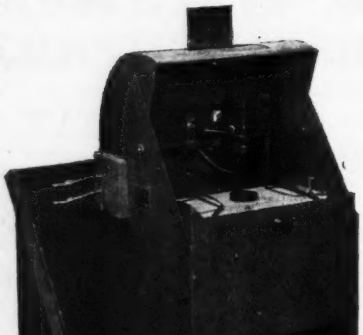
The success of high frequency heating is largely dependent on the availability of equipment which will not only produce ample high frequency energy but also apply it efficiently to the material to be treated. The purchaser must be able to rely on the producer to supply equipment which can be put to production without delay on experimental work. One feature of the Ferranti/Wild Barfield equipment is that it is supplied in a state ready for production work on installation.



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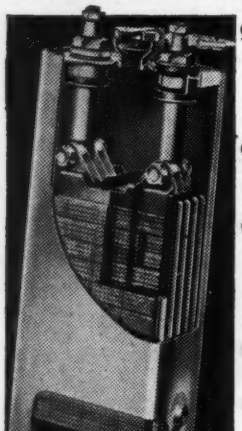

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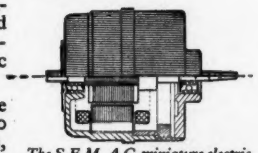

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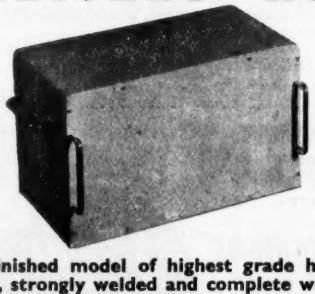

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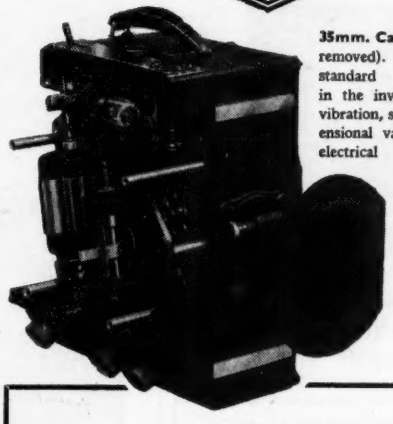

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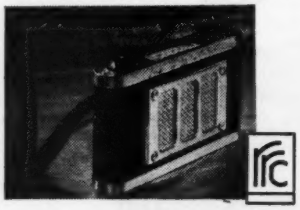

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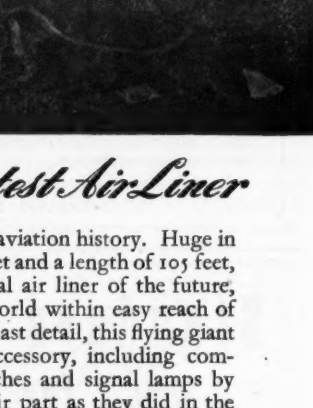

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Candidates must have been born on or after the 2nd August, 1915, and have attained the age of 18 by the 1st January of the year in which they compete. Allowance will be made for service in H.M. Forces prior to 3rd September, 1939.

Men only are eligible to compete for appointment as Assistant Engineer (New Style).

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Age	Men	Women
18	£47	£47
19	£55	£55
20	£63	£59

Male candidates may apply to compete for appointment as Assistant Engineer (New Style) and Assistant Traffic Superintendent at the same examination. There will be prospects of promotion to higher grades. Candidates now serving in H.M. Forces must send in their application forms in time to reach the Civil Service Commission not later than six months after the completion of their service. All other candidates must send them in by 1st April 1947, except that for candidates who are under 18 years old on the 1st April 1947, the latest date for sending in the form is the 1st January following their 18th birthday.

Copies of the Regulations and Forms of Application may be obtained from the Secretary, Civil Service Commission, Burlington Gardens, London, W.1, or from the Chief Officer, Civil Service Commission, at the following addresses, quoting No. 1679.

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(Egypt) 8 Sharia Tolumbat, Garden City, Cairo.
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THE CIVIL SERVICE COMMISSIONERS invite applications for the post of Principal Scientific Officer in the Radar Research and Development Establishment of the Ministry of Supply, to take charge of mathematical investigations arising in the development of radar and associated equipment.

Candidates must be of British nationality, have been born on or before August 1, 1915 and be not more than 50 years of age on November 1, 1946. They must have a first or second class honours degree in mathematics and some research experience in mathematical physics, particularly electromagnetic theory and/or geometrical optics as applied to radio. Knowledge of electronics and circuit analysis would be desirable.

The post is permanent, with superannuation benefits under the Federated Superannuation System for Universities, and carries salary on the Provincial scales £750 by £30 to £1,020 (men) and £660 by £30 to £880 (women) plus a consolidation addition ranging from £90 at the minimum of the scale to £105 at the maximum (men) and from £79 at the minimum to £84 at the maximum (women).

Further particulars and forms of application are obtainable from the Civil Service Commission, 6 Burlington Gardens London, W.1., quoting No. 1721, to whom completed applications must be returned not later than January 13, 1947.

SITUATIONS VACANT

ENGINEER required by large firm in London area for design and development work on fractional horse power motors. Previous experience essential. A degree in electrical engineering is desirable. Write giving full details of experience and qualifications, also salary required, to Box 925, "Elec. Engg."

APPLICATIONS are invited for the following appointments in an engineering company manufacturing electro/mechanical precision instruments on a batch basis:—(a) Production Engineer to take charge of a department comprising process engineering, jig and tool design, rate fixing and tool manufacture. Salary grade: £900-£1,200 per annum.

(b) Production Engineer to determine and control production methods (machining and assembly) on small precision electro/mechanical instruments. Salary grade: £650-£850 per annum. (c) Production Engineer to determine and control production methods on precision electrical components (e.g. coils, chokes, transformers, motors, generators, etc.). Salary grade: £750-£1,000 per annum. The company is situated in the London area and employs about 1,500 people. A pension scheme is available, and the above appointments are eligible for participation after 12 months service with the company. Apply by letter to Box A.C. 14334, Samson Clarks, 57/61, Mortimer Street, London, W.1.

SALES MANAGEMENT. A deputy Sales Manager is required by an engineering company near London, manufacturing and selling precision instruments. Essential qualifications are:—(1) Engineering training, experience and qualifications; (2) Experience in controlling a technical sales department and service department operating on a budgetary control basis; (3) Previous personal association with Government technical and production branches; (4) Experience in export procedures and foreign markets; (5) Age, 30-40 years. The initial salary is between £1,000 and £1,500 per annum and subject to satisfactory service, the successful candidate will be eligible for a higher executive appointment. Apply by letter to Box A.C. 14335, Samson Clarks, 57/61, Mortimer Street, London, W.1.

A FIRM IN LONDON requires communication engineer with considerable experience of radio circuit design especially on aircraft equipment and miniaturisation. Good basic training and subsequent industrial experience essential. Post will be responsible one with very interesting prospects for right man. Initial salary up to £850 per annum. Write full details of education, qualifications and experience to Box 922, "Elec. Engg."

DEVELOPMENT ENGINEER required by company handling a wide range of light electrical, electronic and mechanical devices. Must be fully capable of undertaking, unassisted, the production engineering development of equipment from laboratory models. Applicants should possess a sound basic knowledge of engineering principles and have had extensive experience of similar work. Write giving full particulars of experience and work done, and stating age and salary required to Personnel Manager, P.R.T. Laboratories Ltd., Commonwood House, Nr. Chipperfield, Herts.

CLASSIFIED ANNOUNCEMENTS (CONT.)

SENIOR ENGINEER or Physicist required by Research Laboratories of large group of companies in High Wycombe area, with wide experience of electronics and radio communications, to take charge of laboratory engaged on advanced circuit design and research. A high standard of mathematical knowledge is required. Men with honours degrees in science are preferred. Initial salary according to qualifications and experience, but in the range of £600–£800 per annum. Apply Box 939, "Elec. Engg."

A.M.I.E.E., City and Guilds, etc., on "NO PASS—NO FEE" terms. Over 95 per cent. successes. For full details of modern courses in all branches of Electrical Technology send for our 112-page handbook —FREE and post free. B.I.E.T. (Dept. 337B), 17, Stratford Place, London, W.1.

ELECTRONIC CIRCUIT Development. Large light electrical firm in Middlesex requires the services of a senior engineer for an interesting new development project. The qualifications needed are, five years responsible design experience and an honours degree in physics or electrical engineering. Write giving age, fullest details of education and experience, together with salary required, to Box 937, "Elec. Engg."

BRITISH BROADCASTING CORPORATION Applications are invited from men (British) for two senior posts in the television section of Research Department, based near Oxford in first instance. Applicants must be qualified engineers or physicists and must have specialised in telecommunications during their University training. Experience in practical television problems, together with a sound theoretical knowledge of the principles involved, is essential. Preference will be given to those who have themselves contributed in the field of television research or development. Commencing salary will be dependent on qualifications and experience and, subject to favourable report, will rise by annual increments, in one case to £1,360 per annum and in the other to £1,100 per annum. Applications stating age, qualifications and experience should reach the Engineering Establishment Officer, Broadcasting House, London, W.1. not later than January 8, 1947.

DEVELOPMENT ENGINEER required for West London area. Must have industrial experience, preferably of Audio Frequency Amplifiers, and education to at least Inter. B.Sc., standard. Write, stating age, experience, education and salary required, to Box 936, "Elec. Engg."

RADIO INSTRUCTOR required for Telecommunication Mechanics Course. Qualified City and Guilds Final in Radiocommunciation or equivalent. Lecture, laboratory and workshop experience essential. Apply School of Radio, University College, Southampton.

APPLICATIONS are invited for the post of development engineer in a laboratory in High Wycombe working on radio frequency heating and transmitting equipment. Applicants should be A.M.I.E.E. or equivalent. A sound knowledge of machine design principles is essential. Experience should have covered several of the following subjects: R.F. Induction Heating, Metallurgical Engineering, Electrical Power Distribution and Switchgear, Mechanical or Production Engineering, workshop practice or high power radio transmitting equipment. Salary would between £550 and £650 p.a. according to qualifications. Applications should be addressed to: The Personnel Manager, P.R.T. Laboratories Ltd., Commonwood House, Nr. Chipperfield, Herts.

RADIO TEST ENGINEER required for Inspection Department of important electrical communication company in North London. Must be capable of fitting up test gear and carrying out complete tests on commercial receivers and on airborne transmitter-receiver equipments. A sound knowledge of radio engineering and recognised qualifications essential. Inclusive commencing salary £6 10s. p.w. with good prospects of advancement for keen man. Write Box D.6905., A.K. Advg., 2122, Shaftesbury Avenue, W.C.2.

CONSULTING SERVICE in course of formation invites applications from fully qualified radio and electronic engineers willing to undertake sparetime consulting work at home. Remuneration by agreement. Fullest confidence guaranteed. Applicants should have specialist knowledge of some branch of radio or electronics. Write for further details giving brief summary of qualifications to Technical Advisory Bureau, 42 Barn Lane, Golborne, Nr. Warrington.

ASSISTANT ELECTRICAL DEVELOPMENT Engineer of Degree or Higher National standard with knowledge of electronics and experience of laboratory work on communications and measurements. Permanent position, good prospects. Apply stating age, qualifications and salary desired. Muirhead and Company Ltd., Elmers End, Beckenham.

RADIO DEVELOPMENT engineer required by growing factory on South coast. The position is a highly-paid one; applicants must have had at least seven years theoretical and practical experience in development of components and assemblies. Write giving previous experience and salary required to Box 946, "Elec. Engg."

SENIOR ENGINEER required by Research Laboratories of large group of companies in High Wycombe area, with a wide experience of micro-wave and radar technique. Men with honours degrees in science are preferred. Initial salary according to qualifications and experience, but in the range of £600–£800 per annum. Apply Box 940, "Elec. Engg."

PHYSICISTS REQUIRED by firm in London area for research and development division. An honours degree in physics is essential and some previous research experience is desirable. Applicants should write stating age and experience to Box 944, "Elec. Engg."

SENIOR ENGINEER or Physicist required by Research Laboratories of large group of companies in High Wycombe area with a knowledge of acoustics and preferably with experience of the design of loudspeakers and L.F. amplifiers. Men with honours degrees in science are preferred. Initial salary according to qualifications and experience, but in the range of £600–£800 per annum. Apply Box 941, "Elec. Engg."

ENGINEERS required for research and development department of a firm in the London area. Previous experience on the development of electronic components necessary. Applicants should write stating age and experience to Box 943, "Elec. Engg."

THE MULLARD RADIO Valve Co. require senior radio valve development engineers, degree in electrical engineering or physics essential. Experience in valve development and valve application is desirable. The salary will be in accordance with the company's scale, based on age, qualifications and experience. Applications in the first instance should be in writing addressed to Works Personnel Officer, Mullard Radio Valve Co., New Road, Mitcham Junction, Surrey. Please quote reference R.a.

RESEARCH LABORATORIES of large group of companies in High Wycombe area have vacancy for senior engineer to take charge of laboratory engaged on the design and development of communication type radio receivers and transmitters. Men with honours degrees in science are preferred. Initial salary according to qualifications and experience but in the range of £600–£800 per annum. Apply Box 942, "Elec. Engg."

DESIGNER DRAUGHTSMAN, with telecommunication experience, required for work on electronic measuring apparatus. Write giving details of experience, age and salary required. L.M.K. Manufacturing Co., Ltd., Harlequin Avenue, Brentford, Middlesex.

TEST AND CALIBRATION engineer with telecommunication experience. Must be capable of diagnosis and trouble shooting electronic measuring apparatus. Write giving details of experience, age and salary required. L.M.K. Manufacturing Co., Ltd., Harlequin Avenue, Brentford, Middlesex.

SITUATIONS WANTED

PHYSICIST, Ph. D., age 40, last 16 years in responsible industrial positions, requires change, preferably into research position. Specialist in development of electronic devices (cathode-ray tubes, photocells, radio valves, etc.), electron optics and high vacuum technique, with research, administrative and production control experience. Offers to Box 948, "Elec. Engg."

RADIO COMPONENTS, Engineer, 38, successful executive and administrator, now in charge of development and production of small works, seeks position with increased scope, offering prospects of development for sound and intelligent man with drive. Salary dependent on district but not under £800 p.a. Box 947, "Elec. Engg."

RADAR DISPLAY ENGINEER requires responsible position (at home or abroad) preferably directing research, development or installation re: radar or electronics, etc. 6½ years Government service, 3 years industrial; used to control of people and well travelled. Salary £700–£900. Box 945, "Elec. Engg."

ELECTRONIC ENGINEER, Assoc. Brit.I.R.E., requires responsible position. Design or in charge. Experience: test gear, coils, receivers, etc. Box 950, "Elec. Engg."

RESEARCH ENGINEER with experience in design and handling of projects involving supersonic, electronic, medical, navigational, industrial test and control instruments, will accept similar post. Accustomed to handling staff; aged 26. Salary £600–£700, according to responsibility. Details from Box 949, "Elec. Engg."

WANTED

WE OFFER cash for good modern Communication and all-wave Receivers.—A.C.S. Radio, 44, Widmore Road, Bromley.

HOW LONG will the sellers market in South America go on? Just released Lt.-Col. aged 26, requires to contact progressive and far-sighted manufacturer-exporter of electronic goods with a view to representatives appointment in Argentina, where he intends to settle after necessary learning time here. Capital available if required. Box 938, "Elec. Engg."

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NEW DUAL TESTOSCOPE
Ideal for High and Low Voltage Testing; 1/30,100/850 A.C. and D.C
Send for interesting leaflet L24 on Electrical and Radio Testing, from all Dealers or direct.
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PROCESS TIMERS
Synchronously driven and condenser charge/discharge Timers automatically self-resetting and hand-resetting types for controlling all kinds of industrial processes, plastic presses, chemical actions, welding, etc.
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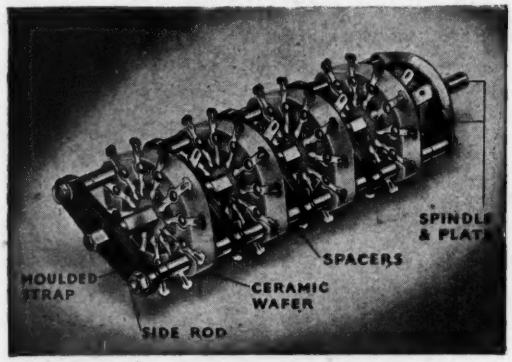
NEWS ITEMS

of interest to the home experimenter

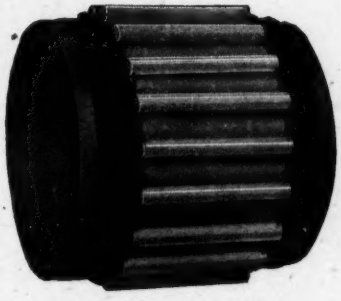


CERAMIC ROTARY SWITCHES

Wearite ceramic rotary switches for your own construction are supplied in individual wafers and components. You assemble any desired combination of contacts to make the finest low-loss switch yet devised. Ideal for the super-efficient receiver and high-grade instrument work. Ceramic switch wafers available in three standard contact arrangements :—

1 Pole 12 way (use index type 12A)
2 Pole 6 way (use index type 6A)
4 Pole 3 way (use index type 3A)

Ceramic wafer	7/0d.
6 in. spindle with Index ..	4/0d.
Side Rod 2½ in. long ..	3d.
„ „ 3¾ in. „	4d.
„ „ 6 in. „.. ..	6d.
Spacers ⅛ in. long	1½d.
„ ¼ in. „	1½d.
„ 2 in. „	4d.
Moulded Straps	8d.
Nuts ... per dozen	3d.



One moulded strap is required for each wafer used. The 6 in. spindle supplied with the three types of Index can be readily cut down to required length.

EXAMPLE OF COSTING :—

Complete ceramic 2 wafer switch, each wafer 1 pole 12 way £1 : 1 : 10d.

A LONG FELT WANT FULFILLED

Oscillator crystals for transmitter control operating on a fundamental frequency of 14 Megacycles now available. **S.T.C. 14 Mc/s Crystals** in evacuated glass bulbs available from stock in a good selection of frequencies covering 10 meter band and also harmonic relationship with the 5 meter band. These crystals are built in miniature " button base " valve envelopes and fit the same valve-holder.
Price : (*Standard Telephones & Cables Ltd.*) . . **35/0d.** each.
We also have very large stocks of Q.C.C. Mounted Crystals for the 7 Mc/s, 3.5 Mc/s, 1.6 Mc/s Amateur Bands. Specify your frequency and we can usually supply exact, or within a kilocycle either way.
Price : (*Quartz Crystal Co.*) .. .. . . **32/6d.** each.

SOME POPULAR S.T.C. AMATEUR TRANSMITTING VALVES

Type 4304CA high frequency Triode, equivalent to type 834. 1,000 v. 100 watts at 100 Mc/s.
Price : .. .. each £ 4: 2 : 6d.

Type 4074A Double Triode, equivalent to RK34 300 v approximately 20 watts at 100 Mc/s, and higher.
An excellent " QRP " power amplifier, also a most efficient " push-push " frequency doubler.
Price : .. .. each £1 : 10 : 0d.

Type 5B/250A, equivalent to 807, well-known general purpose beam power amplifier, ceramic base.
Price : .. .. each £1 : 5 : 0d.

Type 22V/310A, equivalent to type 87 rectifier, 500 v. 250 m.a. D.C.
Price : .. .. each 15 : 0d.

Type 5C/100A, equivalent to 813 beam power R.F. amplifier. 2,000 v. 200/300 watts.
Price : .. .. each £7 : 15 : 0d.

Type 2V/400A Mercury Vapour rectifier, equivalent to 866/866A.
Price : .. .. each £1 : 7 : 6d.

Webb's stock all S.T.C. transmitting valves; list available on request.

RADIO FEEDERS *(illustrated alongside)*

Webb's 600 ohms feeder, something new. Ready built in lengths of 50 and 35 feet. Spacing 3½ in. with 18 gauge wire. Polythene spreaders securely moulded into wire every 20 inches, light and rigid construction. Supplied on drums ready for winding off, and immediate use.

Per 50 foot drum .. .. £1 : 17 : 6d.
Per 35 foot drum .. .. £1 : 6 : 3d.

Packing and despatch extra 2/6d

Co-axial Cable, impedance 80 ohms, outside diameter ⅛ in. any length supplied. Polythene internal insulation weatherproof rubber outer covering. Per yard 1/6d.

Special. Ten yard lengths of ⅛ in. 80 ohms co-axial as above *fitted both ends with co-axial plugs and sockets.* (Supplied only in ten yard lengths) Per length with Plug and sockets .. .. 15/0d.

WEBB'S RADIO

The Short-Wave Specialists

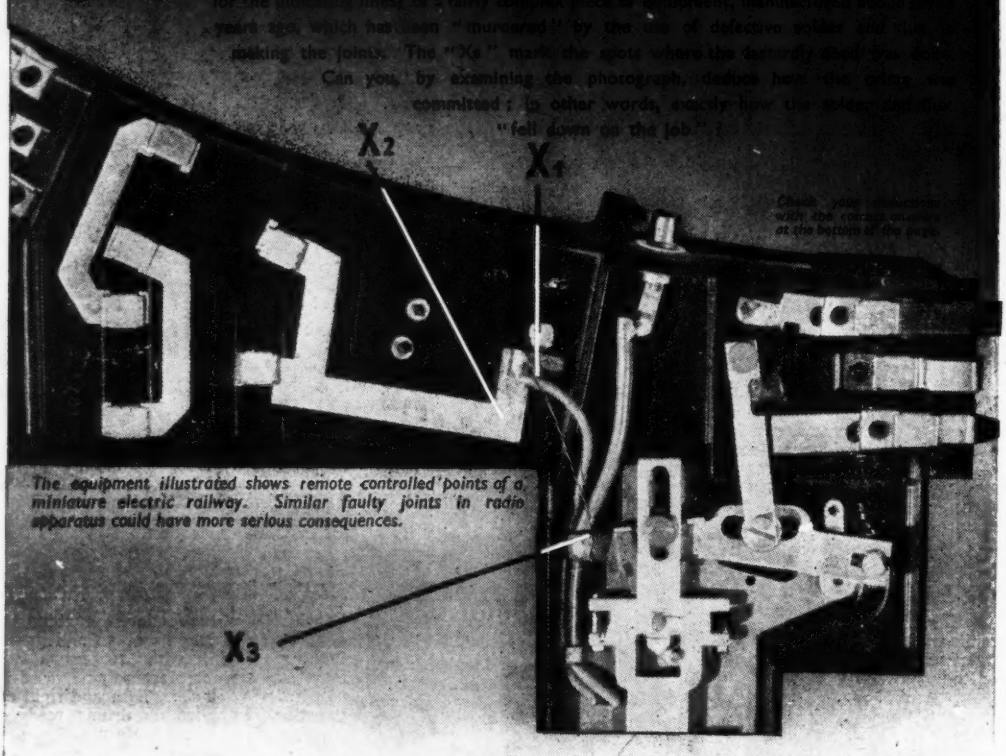
14, SOHO ST., OXFORD ST., LONDON, W.1. 'Phone : GERrard 2089. Hours of Business : 9 a.m. to 5.30 p.m. Sats. 9 a.m. to 1 p.m.

X MARKS THE SPOT

SOLDERING CRIME AND PUNISHMENT

Here is a test of your knowledge of soldering. Below is a photograph (unretouched except for the indicating lines) of a fairly complex piece of equipment, manufactured about [illegible] years ago, which has been "murdered" by the use of defective solder and careless making the joints. The "Xs" mark the spots where the dastardly deed was done. Can you, by examining the photograph, deduce how the crime was committed; in other words, exactly how the solder and the "fell down on the job"?

Check your conclusions with the correct answers at the bottom of the page.



The equipment illustrated shows remote controlled points of a miniature electric railway. Similar faulty joints in radio apparatus could have more serious consequences.

CHECK YOUR ANSWER AGAINST THE SOLUTION BELOW

A wire has been soldered to the strip at the point X1. A corrosive and hygroscopic flux was obviously used. Inevitably the plating of the strip was eaten away and this is now a mass of rust. At the same time, too much flux was applied, so that it ran on to the underside, which is now so rusty that the electrical conductivity between points X1 and X2 is broken. As a result, this piece of equipment, and all its associated equipment, which depends on an electrical circuit, are out of action. At X3 there is no solder at all on the wire, although there is plenty of solder on the tag or strip. Thus only a mechanical joint and not a soldered one has been obtained. Probably no flux, or an insufficient quantity, was applied for this joint.

THE MORAL. Yes, you're quite right; ERSIN MULTICORE SOLDER would have prevented the crime. It contains 3 cores of Ersin Flux (approved by A.I.D. and G.P.O. as being non-corrosive) and its use ensures that exactly the correct proportions of flux to solder are applied. If you are a manufacturer or service engineer of radio or any electrical equipment and do not already enjoy the advantages of ERSIN MULTICORE SOLDER please write for technical information and free samples.

MULTICORE SOLDERS LTD., MELLIER HOUSE, ALBEMARLE ST., LONDON, W.1. REGent 1411. (P.B.X. 4 lines).

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